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SKEW ARCHES.

I.

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I propose in this paper to discuss to some extent three methods which have been employed in the construction of oblique or skew arches, and to make a comparison of their relative security, facility of construction, etc.

The three methods will be designated as,

1st. The Helicoidal method.

2d. The Logarithmic method.

3d. The "Corne de Vache" or Cow's-horn method.

The first two names are derived from the nature of the coursing and heading, joint surfaces and their intersections with the soffit, and the third from the soffit itself, which is a warped surface that has been thus named. They will be considered in the order given above.

The following abbreviations will be used throughout the paper:

C j c, for coursing joint curve, or intersection of coursing joint with soffit.

H j c, for heading joint curve.

C j s, for coursing joint surface.

H j s, for heading joint surface.

H P, for the horizontal plane of projection.

V P, for the vertical plane of projection.

P F, for the plane of the face of the arch.

Ex. s, for the extradosal or outer surface of the arch.

THE HELICOIDAL METHOD.

In this method the C j s's and H j s's are both warped helicoids, and of course their intersections with the soffit helices.

Let C D D_2 C_2 be the projection of the soffit on the H P which coincides with the springing plane of the arch, and D′ V C_2 is a semicircle whose radius will be designated by r.

The Ex. s will be taken as a concentric cylinder projected in A B B_2 H_2 and B′ V′ A_2 and its radius will be designated by r_1.

To construct the C and H j c's we will first develop the soffit. Lay off $O_1 T = \pi = 3{,}1416\ r$; the points of the curve D E F C_1 may be found by the principles of descriptive geometry or by means of the equation of the curve, which we shall obtain. The latter method is much more accurate for construction upon a large scale.

Let $h = D' D_2$, and σ = angle $C_2 D_2 D' =$ obliquity of the arch; $\therefore$ tang. $\sigma = \frac{2r}{h}$.

Also θ = variable angle $s Q D'$. The

origin will be taken first at O_1. We have from the figure

$O_1 \beta = x = r\,\theta.$

$O\,x = \frac{1}{2}h$, E $\beta = -y.$

$$\therefore \frac{\frac{1}{2}h + y}{h} = \frac{r\,(1 - cos\,\theta)}{2r} = \frac{1 - cos\,\theta}{2}$$

$$\therefore \quad 1 - cos\,\theta = \frac{h + 2y}{h}$$

and $$cos\,\theta = -\frac{2y}{h}$$

$$\therefore \quad \theta = cos^{-1}\left(-\frac{}{h}\right)$$

whence $$x = r\,cos^{-1}\left(-\frac{2y}{h}\right).$$

Solving for y we have

$$(1) \qquad y = -\frac{h}{2}\,cos\,\frac{x}{r},$$

which is the equation of D E F C_2 with the origin at O_1. If the origin be moved to O_2 the equation becomes

$$(2) \qquad y = \frac{h}{2}\,sin\,\frac{x}{r}.$$

From either of these equations the values of y for given values of x may be easily obtained by the aid of a table of natural sines and cosines.

Having constructed the curve D E F C_1, join D and C_1 by a straight line. This will be the development of a H j c. At O_2 draw O_2 S perpendicular to D C_1. O_2 S is the development of $\frac{1}{4}$ of a spire of the helix which forms the C j c's, and corresponds to the curve O P R.

The angle $TO_2S = TC_1O_2 = tang.^{-1}\frac{\pi r}{h}$

$$\therefore TS = O_2T\,tang\,\angle\,O_2S = \frac{\pi^2 r^2}{2h} = \tfrac{1}{4}\pi^2 r\,tan\,\alpha$$

Now divide D E F C_1 into a convenient odd number of equal parts, so arranging it as to cause one of the C j c's as δ D_2 to pass through D_2. The developments of the C j c's are of course drawn parallel to O_2 S through the points of division of the curve D E F C_1. If it were not convenient to divide D E F C_1 in such a manner that a line through D_2 parallel to O_2 S would exactly pass through one of the points of division, the direction of the C j c's might be slightly changed, or the divisions between D_2 δ and C_2 δ might be made very slightly larger or smaller, as the case required, then the divisions from D to δ and from C_2 to δ'. The latter method seems preferable, since it preserves the perpendicularity between the C and H j c's, and the difference in the size of the voussoirs would be so small as not to be noticeable.

All the courses below δ and δ_1 run out into the abutment, and the impost must be cut in steps, as shown in the figure, into which the voussoirs will fit.

A G H B_1 is the development of the extrados, and the right line $x\,y$ that of a helix in which one of the H j s's intersects the Ex. s. O_4 R_1 is the development of the curve O L R_1, in which a C j s intersects the Ex. s.

$$Tan\,x\,y\,O_3 = \frac{h}{\pi r_1}.$$

$$Tan\,O_3\,O_4\,R_1 = \frac{T\,S}{\frac{1}{2}\pi\,r_1} = \frac{\pi^2\,r^2}{2h} \div \frac{\pi\,r_1}{2} =$$

$$\frac{r}{r_1}, \frac{\pi\,r}{h} = \frac{\pi\,r}{2\,r_1}\,tan\,\alpha.$$

The C j s's are generated by a right line moving on the axis O Q as one directrix, the helix O P R as a second, and remaining always perpendicular to the former. Hence the V P is a plane directer of the surface.

The details of the construction of a skew arch by this method are fully developed in "A Practical and Theoretical Essay on Oblique Bridges," by John Watson Buck, M. Inst. C. E. He, however, makes the C and H j s's *hyperbolic paraboloids* instead of helicoids, as follows: The corners of the voussoirs are normals to the soffit at the intersection of the H and C j c's, and hence are elements of the warped helicoids, which *should* form the H and C j s's. The points where two of the normals on the same side of the voussoir pierce the soffit are joined by a right line, and this line is moved on the normals as directrices in such a manner as to pass over equal distances, measured on the normals in equal times, by which operation a hyperbolic paraboloid is generated. The accompanying figure is an exaggerated representation of the effect of cutting the stones in this manner. A B C D and E F G H are the developed introdosal surfaces of two voussoirs in successive courses. If the courses were not required to break joints, the stones would fit perfectly, but as this is necessary to the stability of the

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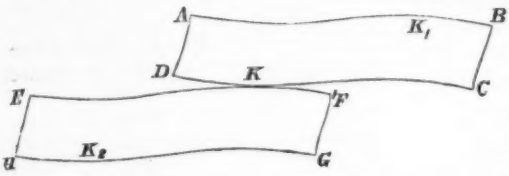
arch, that portion of a stone which is too full will come opposite to the portion of the one in the next course which is likewise too full, and similarly the hollow portion of one opposite to the hollow portion of the next.



The truth of these statements will appear as follows: The hyperbolic paraboloid evidently cannot coincide with the helicoid, as they are surfaces constructed according to a different law. The normals to the two adjacent corners of a voussoir are elements of both surfaces. The normal midway between these two is also an element common to the two surfaces. Hence it is evident from the mode of their generation that the two surfaces intersect each other along each of these three lines. A section of the surfaces by a plane perpendicular to the middle normal would give something like the accompanying figure, ⌒ the straight line being the intersection with the hyperbolic paraboloid and the curve that with the helicoid.

However, if the voussoirs are small compared with the whole arch, as in Fig. 1, the difference between the paraboloidal and helicoidal surfaces in the length of one voussoir will be exceedingly small, and the stones will fit with sufficient exactness for practical purposes. Nevertheless, the *tendency* is to cause the pressure to be unequally distributed, concentrating it at K, K_1, K_2 and at A, C, E and G. The difficulty of cutting the warped faces of the voussoirs is considerably diminished by this approximate method.

An investigation will now be made of the security of an arch constructed according to the helicoidal method.

In order that there may be *no* tendency in the successive courses to slide upon each other, it is evident that each C j s must be at every point normal to the direction of the pressure at that point. We shall consider first the direction of pressure as regards its parallelism to a certain vertical plane, without reference to the angle it may make at any point with the H P. This vertical plane is the place of the face of the arch. It is probable that the direction of pressure varies somewhat with reference to this plane in different portions of the arch, especially if the crown settles to any extent after removal of the centre. Still it must be approximately parallel to the P F, otherwise the portions near B and A_2 would be unsupported and would consequently fall. For the purposes of the investigation then the direction of pressure will be *assumed* to be in a plane parallel to the P F, and from the results obtained we shall be able to see without difficulty the effect upon the security of the arch which would be produced if the direction of pressure were *not* parallel to the P F. Proceeding then on this assumption, a line drawn on the C j s of any voussoir and lying in a plane perpendicular to the P F and to the H P *ought* to be *horizontal*, but as this line would be the intersection of a warped helicoid by a plane not containing an element of the surface, it must be a *curve*, and can only be horizontal at a maximum or a minimum point, at infinity, or at some singular point. The intersection of the C j s of a voussoir by a *horizontal* plane should give a line perpendicular to the P F, but this line would be also a curve, and could have the required direction only at one or more points. It becomes necessary then to discover the nature of these curves and the direction of their tangents at the point of piercing the soffit.

In Fig. 1 (Frontispiece) the curves Q P'_4 *a*, Q P'_3 *b*, etc., are the vertical projections of the curves cut by the vertical planes, P_4 *c*, P_3 *k*, etc., from the helicoid whose directrices are the axis O Q and the helix O P R. The curve Q P′*c* has a maximum point at P P′ where it pierces the soffit; all those above it have a maximum point *outside* the soffit, and those below it have one *inside* the same.

The curves O P_4 *r*, O P_3 *q*, etc., are cut by horizontal planes through the points P_4 P'_4, P_3′, etc. The curve through P is not drawn, but if it were it would be tangent at P to the line P *h*.

It is plain from inspection of these curves

that the courses below P P′ have a tendency to slide upon each other in a direction from A_1 towards A, which increases as the abutment is approached. In Fig. 1 this point P P′ is on the tenth course from the abutment, and there are three coursing joints which would have a tendency to slide throughout their whole length with nothing to resist it except friction between the surfaces. The *partial* courses would be prevented from sliding by the steps cut in the impost. Above P P′ the tendency to slide would be in the opposite direction, but would be so small as not to affect seriously the stability of the arch. This will be evident from inspection of the curves O P_1 p and O P_2 o.

We will now investigate these curves analytically and determine the position of the point P P′.

The distance T S, Fig. 1, is $\frac{1}{4}$ the height of one spire of the helix O P R, and from eq. (3) $T S = \frac{3\pi r^2}{2h} = \frac{1}{4}\pi^2 r \tan \alpha$.

Call the height of one spire of the helix h_1, then

$$h_1 = \frac{2\pi^2 r^2}{h} = \pi^2 r \tan \alpha.$$

Let O be the origin of coördˢ, the axis of the cylinder, O Q, the axis of Z, O T the axis of x, and the axis of y a vertical line through O. Then we shall have for the helix O P R.

$$\frac{\theta - \frac{\pi}{2}}{2\pi} = \frac{z}{h_1};$$

whence $\theta = \frac{2\pi z}{h_1} + \frac{\pi}{2}$.

Also

$$x = r\cos\theta = r\cos\left(\frac{2\pi z}{h_1} + \frac{\pi}{2}\right) = -r\sin\frac{2\pi z}{h_1},$$

or substituting for h, its value

$$(4) \qquad x = -r \sin \frac{h z}{\pi r^2}$$

which is the equation of O P R, the projection on X Z of one of the C j c's. The vertical projection, or the projection on X Y of this helix is

$$(5) \qquad x^2 \times y^2 = r^2.$$

To obtain the equation of the C j s, we must find the equations of an element, and then eliminate the constant which fixes its position. Let one equation of the element be

$$(6) \qquad z = z_1.$$

To find the equation in terms of x and y, substitute in the equation

$$\frac{y - y_1}{x - x_1} = \frac{y_1 - y_2}{x_1 - x_2}$$

of a line through two points the proper values of x_1, x_2, y_1 and y_2. We have since all the elements cut the axis of z,

$$x_1 = o \text{ and } y_1 = o.$$

Substituting from (6) in (4)

$$x_2 = -r \sin \frac{h z_1}{\pi r^2},$$

and substituting this value of x_2 in (5),

$$y_2 = \sqrt{r^2 - r^2 \sin^2 \frac{h z_1}{\pi r^2}} = r\sqrt{1 - \sin^2 \frac{h z_1}{\pi r^2}}$$

$$= r \cos \frac{h z_1}{\pi r^2}.$$

$$\therefore \frac{y}{x} = -\frac{r \cos \frac{h z_1}{\pi r^2}}{r \sin \frac{h z_1}{\pi r^2}} = -\cot \frac{h z_1}{\pi r^2};$$

or making z_1 general by dropping the subscript,

$$(7) \qquad y = -x \cot \frac{h z}{\pi r^2},$$

which is the equation of a C j s.

Now, intersect this surface by a vertical plane perpendicular to the P F, whose equation is

$$(8) \qquad z = \frac{2r}{h}(a_1 - x),$$

in which a_1 is the intercept on X.

$$(9) \qquad \therefore y = -x \cot \left(\frac{2(a_1 - x)}{\pi r}\right)$$

which is the equation of the curves Q P′ c, etc.

In equation (9) if

$$x = o, \quad y = o;$$

if $x = a_1 - \frac{(2n-1)\pi^2 r}{4}$,

$$y = -x \cot \frac{(2n-1)\pi}{2} = 0,$$

n being an integer;

if $x = a_1 - \frac{n\pi^2 r}{2}$,

$$y = -x \cot n\pi = \infty,$$

n as before being an integer. Hence the curve has an infinite number of branches. It is to be noticed that equation (9) *does not contain* h, the only constants being π, a_1 and r, *hence the form of the curves* $Q\,P'\,c$, $Q\,P_1'\,d$, etc., *is entirely independent of the obliquity of the arch.* We will next differentiate equation (9) for a maximum.

$$\frac{dy}{dx} = -\cos\left(\frac{2(a_1-x)}{\pi\, r}\right) - \frac{2\,x}{\pi\, r \sin^2\left(\frac{2(a_1-x)}{\pi\, r}\right)}$$

Let $\dfrac{2\,(a_1-x)}{\pi\, r} = u$

$$(10)\quad \therefore \quad \frac{dy}{dx} = -\cot u - \frac{2\,x}{\pi\, r \sin^2 u}$$

For a maximum

$$\cot u = -\frac{2\,x}{\pi\, r \sin^2 u}.$$

$$(11)\quad \therefore x_{ymax} = -\frac{\pi\, r \sin u \cos u}{2}.$$

By solving equation (11) the values of x for which y is a maximum or minimum can be obtained. It is only capable, however, of an approximate solution, but if we obtain the x co-ordinate of the intersection of the locus of equation (9) with the circle

$$(12)\qquad x^2 + y^2 = r_2^2,$$

in which r_2 may have any value, and place this value of x equal to that in equation (11), we shall obtain the value of x_{ymax} when the maximum point is at the intersection of the two curves.

$\therefore$ substituting from (9) in (12)

$$x_1^2 + x_1^2 \cot^2 u_1 = r_2^2$$

$$x_1^2 (1 + \cot^2 u_1) = x_1^2 \operatorname{cosec}^2 u_1 = r_2^2.$$

$$(13)\qquad \therefore \quad x_1 = r_2 \sin u_1.$$

$\therefore$ by (11) and (13),

$$r_2 \sin u_1 = -\frac{\pi\, r \sin u_1 \cos u_1}{2}$$

$$\therefore \quad \cos u_1 = -\frac{2\,r_2}{\pi\, r}$$

$$\frac{2\,(a_1 - x_1)}{\pi\, r} = u_1 = \cos^{-1}\left(-\frac{2\,r_2}{\pi\, r}\right)$$

$$\therefore \quad \psi_1 = a_1 - \frac{\pi\, r}{2}\cos^{-1}\left(\frac{2\,r_2}{\pi\, r}\right).$$

Denoting by x_{ml} the value of x for which y is a maximum when the locus of (9) is subject to the condition of having a maximum point at its intersection with $x^2 + y^2 = r_2^2$, and substituting the value of x just found in the 2d member of (13), we have

$$x_{ml} = r_2 \sin\left\{\frac{\left(2\,a_1 - a_1 + \frac{\pi\, r}{2}\cos^{-1}\left(-\frac{2\,r_2}{\pi\, r}\right)\right)}{\pi\, r}\right\}$$

$$= r_2 \sin \cos^{-1}\left(\frac{2\,r_2}{\pi\, r}\right)$$

$$= r_2 \sin \sin^{-1}\sqrt{1 - \frac{4\,r_2^2}{\pi^2\, r^2}}$$

$$= r_2 \sqrt{\frac{\pi^2\, r^2 - 4\,r_2^2}{\pi^2\, r^2}}$$

$$(14)\quad \therefore \quad x_{ml} = r_2 \frac{\sqrt{\pi^2\, r^2 - 4\,r_2^2}}{\pi\, r}$$

Let $r_2 = r$, this being the condition that the maximum point shall be at the point where the locus of (9) pierces the soffit, and we have

$$(15)\quad x_{ml} = \frac{r}{\pi}\sqrt{\pi^2 - 4} = r \cos \tau.$$

Whence

$$(16)\quad x_{ml} = 0.77118r = r \cos 39^\circ\, 32'\, 23''.$$

This value of τ may also be found by means of the curves OP_1p, OP_2o, etc. Intersect the surface of equation (7) by the horizontal plane

$$(17)\qquad y = b.$$

$$\therefore \quad b = -x \cot \frac{h\,z}{\pi\, r^2}$$

$$(18)\quad \text{or} \quad x = -b \tan \frac{h\,z}{\pi\, r^2},$$

the equation of the curves OP_1p, etc.

Differentiating

$$(19)\quad \frac{dr}{dx} = -\frac{\pi\, r^2}{b\,h}\cos^2\frac{h\,z}{\pi\, r^2}$$

If $z = \pm\dfrac{\pi^2\, r^2}{2\,h}$ in (18) and (19) we have

$$x = \backsim \text{ and } \frac{dr}{dx} = 0,$$

showing that the lines $z = \pm\dfrac{\pi^2\, r^2}{2\,h}$ are asymptotes of the curves.

Intersect the circle $x^2 + y^2 = r_2^2$ by $y = b$

$$\therefore \quad x_1 = \pm\sqrt{r_2^2 - b^2}.$$

Substitute this value of x in (18) and $\pm_1\sqrt{r_2^2 - b^2} = -b \tan \dfrac{h\,z_1}{\pi\, r^2}$; whence

$$(20)\quad z_1 = \frac{\pi\, r^2}{h}\tan^{-1}\left(\frac{\mp\sqrt{r_2^2 - b^2}}{b}\right)$$

z_i is the z co-ordinate of the point in which the locus of (18) pierces the cylinder, concentric with the soffit, whose radius is r_2.

Substitute from (20) in (19), thus

$$\frac{dz_i}{dx_i} = -\frac{\pi r^2}{b\,h}\cos^2\left\{\tan^{-1}\left(\frac{\pm\sqrt{r_2^2-b^2}}{b}\right)\right\}$$

$$= -\frac{\pi r^2}{b\,h}\left\{\cos\cos^{-1}\frac{1}{\sqrt{1+\frac{r_2^2-b^2}{b^2}}}\right\}^2$$

$$(21) \qquad = -\frac{\pi\,b}{h}\left(\frac{r}{r_2}\right)^2$$

If $r_2 = r$, when the cylinder mentioned above becomes the soffit,

$$(22) \qquad \frac{dz_i}{dx_i} = -\frac{\pi\,b}{h},$$

which is the tangent of the angle between the tangent to the locus of (18) and the axis of x at the point where the locus pierces the soffit. If we make the condition that

$$(23) \qquad \frac{dz_i}{dx_i} = -\frac{2\,r}{h},$$

that is, that the tangent at this point shall be perpendicular to the P F, we have from (22) and (23)

$$\frac{\pi\,b_1}{h} = \frac{2\,r}{h}$$

$$(24) \quad \therefore b_1 = \frac{2r}{\pi} = 0.63662\,r = r\sin 39°\,32'\,23''$$

which agrees with equation (16).

It is thus apparent that in an arch constructed by this method the portions below PP′ or beyond the line $\eta\gamma$ on the development, should be *omitted; i.e.*, the arch should be *always segmental* with a span not exceeding

$2\,r\cos\tau = 2\,r\cos 39°\;32'\;23'' = 1.54236r$,

provided that there is to be no tendency in the successive courses to slide on one another. The amount of this tendency to slide and its relation to the obliquity of the arch will next be investigated.

Let us obtain an expression for the angle $\zeta\,P_4\,\mu$ between the tangent line to O $P_4\,r$ at P_4 and the line $P_4\,\zeta$ perpendicular to the P F. Let $\zeta\,P_4\,\mu = \theta'$ then, equation (22),

$$\theta' = \tan^{-1}\frac{2\,r}{h} - \tan^{-1}\frac{\pi\,b}{h}$$

(25)

$$\therefore \tan\theta' = \tan\left(\tan^{-1}\frac{2\,r}{h} - \tan^{-1}\frac{\pi b}{h}\right) =$$

$$\frac{\frac{2\,r}{h} - \frac{\pi\,b}{h}}{1+\frac{2\,\pi\,b\,r}{h^2}} = \frac{h\,(2\,r-\pi\,b)}{h^2+2\,\pi\,b\,r}$$

If $h = o$, $\tan\theta' = o$, $\therefore\ \theta' = o$.

If $h = \infty$ $\tan\theta' = o$, $\therefore\ \theta' = o$.

θ' must be equal to θ when $\tan\theta' = o$ because it can never equal, much less exceed 90°; for if it *can* equal 90°, then we must have from (25)

$$h^2 + 2\,\pi\,b\,r = 0;$$

$$\therefore\ h = \sqrt{-2\,\pi\,b\,r};$$

i. e., h must be imaginary. It follows that there must be some value of h for which $\tan\theta'$ and therefore θ', is a maximum. By placing the first differential co-efficient of the function with reference to $h = s$, we find this value to be

$$(26) \qquad h = \sqrt{2\,\pi\,b\,r}.$$

By this equation $h = 2\,r\,cot\,\alpha = 1.0445\,r$,
$\theta'^{\max}$ $\theta'^{\max}$

when $b = r\sin 10°$ $\therefore\ \alpha = 62°\ 25'$ for
$\theta'^{\max}$

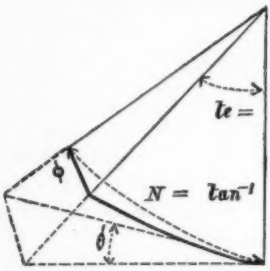
this value of b.

Now the tendency to slide at any point, as $P_4\,P_4'$, depends upon the angle between the normal to the C j s at that point and the direction of the pressure. This last we have assumed to be in a plane parallel to the P F. We will now assume for the purposes of the investigation that it coincides at the point P_4P_4' with the direction of the tangent at that point to the ellipse cut from the soffit by a plane through the point parallel to the P F. Let p_1 = tangent of angle between ground line and tangent line to curve $Q\,P_4'\,a$ at the point P_4'; then the tangent of the angle between the tan line to this curve in space at the point $P_4\,P_4'$ and the H P will be $= p_1\cos\alpha$.

Let p_2 = tangent of angle between a vertical line and the tangent line to the circle D′ V C_2 at the point P_4' = angle $P_4'\,Q\,C_2$, then the tangent of the angle between a vertical and the tangent line at $P_4\,P_4'$ to the section of the soffit parallel to the P F will be $= p_2\,\mathrm{cosec}\,\alpha$.

Now to find the angle between the normal at $P_4\,P_4'$ to the C j s, and the tangent to the section parallel to the P F, we have given two sides and the included angle of a spherical triangle, the included angle being θ'.

Let N = angle between normal to C j s, at P_4 P_4' and vertical = angle be-



tween tangent plane to C j s at P_4 P_4' an H P, then we find the value of tan N to be tan N = $p_1 \cos \alpha \operatorname{cosec} \theta'$.

$$(27) \quad \therefore \sin N = \frac{p_1 \cos \alpha \operatorname{cosec} \theta'}{\sqrt{1 + p_1^2 \cos^2 \alpha \operatorname{cosec}_2 \theta'}}$$

$$(28) \quad \cos N = \frac{1}{\sqrt{1 + p_1^2 \cos^2 \alpha \operatorname{cosec}^2 \theta^1}}$$

and if $t_o = \tan^{-1}(p_2 \operatorname{cosec} \alpha)$, we have

$$(29) \quad \sin t_o = \frac{p_2 \operatorname{cosec} \alpha}{\sqrt{1 + p_2^2 \operatorname{cosec}^2 \alpha}}$$

$$(30) \quad \cos t_o = \frac{1}{\sqrt{1 + p_2^2 \operatorname{consec}^2 \alpha.}}$$

By spherical trigonometry

(31) $\cos \Phi = \cos N \cos t_o + \sin N \sin t_o \cos \theta'$; whence, by substitution

$$(32) \quad \cos \Phi = \frac{1 + p_1 p^2 \cot \alpha \cot \theta'}{\sqrt{(1 + p_1^2 \cos^2 \alpha \operatorname{cosec}^2 \theta')\,(1 + p_2^2 \operatorname{cosec}^2 \alpha)}}$$

Multiplying numerator and denominator by $\sin \alpha \sin \theta'$, this becomes

$$(33) \quad \cos \Phi = \frac{\sin \alpha \sin \theta' + p_1 p_2 \cos \alpha \cos \theta'}{\sqrt{(\sin^2 \theta' + p_1^2 \cos^2 \alpha)\,(p_2^2 + \sin^2 \alpha)}}$$

If in this equation $\alpha = o$, then by equation (25), since $h = 2 r \cot \alpha$, $\theta' = o$, and hence $\cos \Phi = \frac{p_1 p_2}{p_1 p_2} = 1$, $\therefore \Phi = o$.

If $\alpha = 90° - i.e.$, the obliquity = 0—by (25) $\theta' = 0$, and hence cos $\Phi = \frac{0}{0}$ indeterminate. The reason for this is, that the tangent lines to the curves $\mathfrak{C}$ P_4» $QP_4'a$, and OP_4r»$P'_4\pi$ by which we have fixed the position of the tangent plane *coincide* when $\alpha = 90°$. The value towards which cos Φ *approaches*, however, is unity, as α approaches 90°, for from the relations between the quantities it is evident that when $\theta' = 0$, N must equal t_o, and hence by equation (31),

$\cos \Phi = \cos^2 t_o + \sin 2 t_o = 1$; $\therefore \Phi = o$.

It follows, therefore, that there must be some value of α for which cos Φ is a minimum, and therefore Φ a maximum, for any given values of p_1 and p_2. Owing to the complexity of the expression for cos Φ, this value would be very difficult to obtain by differentiation; but it can be determined approximately by calculating a series of values of cos Φ for different values of α. This has been done, with the following results:

The point for which the calculations are made is P_4 P'_4, for which

$x = -r \cos 10°$, $y = b = r \sin 10°$, $z = \frac{4 \pi^2 r^2}{9 h} p_2 = \tan 10°$, and $p_1 = 0.47011 = \tan 25° 10' 43''$, the value of p_1 being found by equation (10).

TABLE I.

When $\alpha = 60°$, $\theta' = 34° 42' 41''$, and $\Phi = 14° 57' 30''$

" $\alpha = 40°$, $\theta' = 27° 10' 00''$, " $\Phi = 25° 27' 00''$

" $\alpha = 30°$, $\theta' = 21° 3' 00''$, " $\Phi = 31° 00' 00''$

" $\alpha = 20°$, $\theta' = 14° 19' 50''$, " $\Phi = 34° 44' 00''$

" $\alpha = 10°$, $\theta' = 7° 14' 50''$, " $\Phi = 29° 57' 00''$

From this table it appears that Φ is a maximum when α has some value not far from 20°.

If the point considered be P P′ for which $x = r \cos \tau = r \cos 39° 32' 23''$, and

$$y = b = r \sin 39° 32' 23'',$$

we have $\theta' = o$ and $p_1 = o_1$ $\therefore$ in equa-

tion (33) $\cos \Phi = \frac{0}{0}$, and from the same considerations as when $\alpha = 90°$, we find

$$\cos \Phi = 1, \text{ whence } \Phi = o,$$

without reference to what the value of α may be.

If, as is very probably the case, the direction of pressure is *not* exactly parallel to the P F, but inclines somewhat towards the plane of the right section of the soffit, the effect will be to *increase* the tendency to slide on the C j s's. Near the springing plane, however, the direction of pressure in a vertical plane will not be exactly parallel to the tangent to the oblique section, but will make a *less* angle with the H P, which will tend, especially when the obliquity is considerable, to counteract the previously mentioned effect. This refers to portions of the arch *below* P P′ for which $y = r \sin 39° 32' 23''$; *above* this, the tendency to sliding being in the *opposite direction*; if the line of pressure incline towards the plane of right section, it will decrease this tendency, and thus add to the stability of the arch. It is evident from inspection of the table of values of Φ that a *full centred* arch should not be built by this method unless with a small obliquity, and then it would need to be thoroughly supported by the spandrels.

These results differ entirely from those obtained in Chap. VII. of Buck's treatise on oblique arches already referred to; in fact, are in direct opposition to them. He derives a formula for the value of τ *dependent upon the obliquity of the arch*, so that τ decreases with α, or as the obliquity increases, and infers therefrom that the safety of the arch *increases* as it becomes more oblique up to about 25°. I should state that his τ has a slightly different signification from mine. He undertakes to find the point at which the curves Q P′*c*, Q P′*d*, etc., cut the intrados and extrados at the *same height* above the H P, and calls the angle included between a radius drawn to this point of the intrados and the H P the angle τ. It will be evident from inspection of the drawing that this would give to τ a somewhat *greater* value than I have obtained, but still *independent* of α, since the only constants in equation (9) are a_1, π, and r.

The following table taken from his book gives the values of τ obtained by Buck from his formula for certain values of α, from which he derives his inferences with reference to the security of oblique arches.

TABLE FROM BUCK'S ESSAY ON OBLIQUE BRIDGES.

When	$\alpha = 65°$,	then	$\tau = 27° 17'$
"	$\alpha = 55°$,	"	$\tau = 25° 13'$
"	$\alpha = 45°$,	"	$\tau = 21° 47'$
"	$\alpha = 35°$,	"	$\tau = 15° 38'$
"	$\alpha = 25° 40'$	"	$\tau = 0° 0'$

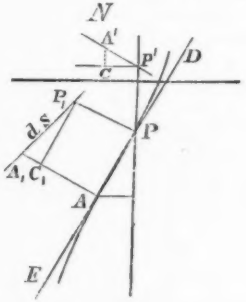
Immediately under this table he remarks, "It will be observed that the last angle is given 25° 40′, at which the point τ descends to the level of the axis of the cylinder, and *the whole semicircle is safe.*"* By looking at the table of values of Φ it will be seen that, for this value of α, Φ will be about 32° or 33° at 10° above the springing plane, τ of course being 39° 32′ 23″ instead of *o*, and hence the arch will be anything but safe if a complete semicylinder.

One incorrect assumption made by Buck in his derivation of the formula for the value of τ is as follows. He says: "It may be shown that the tangent of the angle which the tangent to the intradosal spiral makes with the horizon diminishes as cos τ." He does not show it, however.

Call the above mentioned angle ψ, and the angle between the tangent to the helix at any point and axis of the cylinder β, then the true relation is

$$\sin \psi = \sin \beta \cos \tau$$

$$\tan \psi = \frac{\sin \beta \cos \tau}{\sqrt{1 - \sin^2 \beta \cos^2 \tau}}.$$



In the figure suppose A P to be the horizontal projection of an element $d s$ of

*The *italics* are mine.

the helix coinciding with the tangent line D E. A′ P′ is its vertical projection, and $A_1 P_1$ its revolved position about a horizontal line in a vertical plane through P. The angle $A_1 P_1 C_1 = \psi$, and the angle $C A' P' = \tau$.

$\therefore ds \sin \psi = A_1 C_1 = A' C = A' P' \cos \tau$;

but $A' P' = ds \sin \beta$;

$\therefore \quad \sin \psi = \sin \beta \cos \tau.$

At the springing plane the tangent to the elliptical section parallel to the P F becomes vertical, and the value of Φ is

$$(34) \quad \tan \Phi = \frac{h}{\pi r} = \frac{2}{\pi} \cot \alpha.$$

At the crown it is

$$(35) \quad \tan \Phi = \tan \theta' = \frac{(2 - \pi) \cot \alpha}{2 \cot^2 \alpha + \pi}$$

The following is a table similar to table I, giving the values of Φ at the crown and springing plane, derived from equations (34) and (35).

TABLE II.

	At the Crown.	At the Springing Plane.
When $\alpha = 60°$	$-\Phi_{cy} = 9° 50'$	$\Phi_{sp} = 18° 20'$
" $\alpha = 50°$	$-\Phi_{cy} = 11° 53'$	$\Phi_{sp} = 28° 7'$
" $\alpha = 40°$	$-\Phi_{cy} = 12° 49'$	$\Phi_{sp} = 37° 11$
" $\alpha = 30°$	$-\Phi_{cy} = 9° 16'$	$\Phi_{sp} = 47° 48'$

$\Phi_c = \theta_c'$ is a maximum by equation (26) when $\alpha = 38° 35'$, for which value of α we find $\theta_c = 12° 50'$.

At the angle $\alpha = 25° 40'$—the last one given in the table extracted from Buck's work—the line which he finds to be horizontal makes an angle with the H P of a little more than 29° 51′, that being the angle between the tangent to the locus of equation (9) at the point R» C_2 and the H P.

It will be noticed that the negative sign of Φ_c in Table II. comes from the fact that in equation (35) π is greater than 2. It indicates that the tendency to sliding is in the *opposite direction* from what it is below τ.

THE STREET-PAVEMENT QUESTION.*

From the "Journal of the Society of Arts."

It would not be easy to find an illustration of the waywardness of public opinion, and of the inability, mental or moral, of the great mass of people, to award righteous judgment upon the various facts which are before them, clearer than appears in the controversy carried on as to the merits of wood and asphalte for pavements.

Interest and caprice struggle against manifest public utility, and it will be by accident, or by something more sordid, that the best will win. When these two forces contend, public good is too often used on either side as mere pretence.

1. It is submitted that impartial examination of the facts determines the conclusion that asphalte is the best known pavement. It has more of the qualities that are useful, and less of the undesirable, than any other substance.

2. Friction—resistance to moving bodies—is the unavoidable difficulty in the way of easy and rapid street transit. Asphalte causes the least friction. It is almost as smooth as the iron rail itself, and it is moreover elastic. Hence horse power is by it economized greatly. A heavier weight with equal power can be moved over asphalte than over wood or stone, except it be on steep gradients. Equal horse power will move a greater weight, hence asphalte is a better and kinder economy. A horse will draw his old usual load—almost always the utmost he can move—with less fatigue, thus that costly and interesting laborer, the horse, can live and work longer, and will therefore be rendered more profitable to his master.

3. The horse will have a more comfortable life of it by reason of asphalte. In these times, when such refined interest is lavished on the working classes of all sorts, the horse has some claim to be considered in public improvements, seeing that he is about the best behaved of his order, rarely requiring the policeman, and rarely deserving the whip, certainly not oftener than some other classes of workers. He joins not unions, nor strikes; in truth he submits but too quietly to some-

* From a Paper presented to the Society of Arts.

times very hard usage and hard fare. Greed unfortunately deprives him of the agreeable advantages of asphalte, and because he can now draw more than his former normal load, he is made to draw more. Some time ago, when it was proposed to raise and level Holborn valley, humanity urged claims on behalf of the horse; it was said he would not be urged to draw so heavy a load up hill. An astute person said such is a mistake. "Level Holborn hill, and the horse will be the sufferer in the long run. Now, in his course from Aldgate to Oxford street he is loaded in reference to the difficulty of the hill, and therefore he is loaded under his strength for all the long remainder of his journey. Fill up Holborn hill, and more will be wrung out of him." This applies already to tramways, and will be applied generally to asphalte. The horse is no gainer, alas!

4. By reason also of its little friction, asphalte wears away and abrades moving bodies less, and thus it creates less dust. Its elasticity, though little heeded, helps this. Of its own proper substance the least possible is worn away. Some say it is not worn at all, but is forced out of perfect level and rolled closer, especially when there is continued pressure in one narrow line or groove. Hence it is not so well suited for narrow streets. Probably asphalte pulverizes less than any known body.

5. Asphalte is in itself clean, in itself or from its own abrasion, or it is clean compared with any other kind of pavement. It may be kept clean with the least labor and cost. All matters—and there are many—which are offensive to the senses and to the health, can be and are at once easily removed with even little or no stain. The cartway may be kept nearly as clean as the footway. Asphalte presents an even, smooth, and continuous surface. All other materials are joined, and the joinings are receptacles for the worst compounds of mud and dust. Hence the footway derives much of its dirt. Utmost cleanness is a prime condition of health and comfort. Dirt begins with the street, and ends inside the house, from the cellar to the attic, wherein are blown the unsavory matters of the street when in the state of dust. Asphalted clean streets are now especially required, seeing that disguised under fashionable costume, ladies—*i. e.*, those who do not ride in carriages—resolutely employ themselves in sweeping the dirtiest of the streets, whether of the mud or dust. The costliest and most delicate fabrics, gracefully or not gracefully attached to their persons, do the work of the besom or "squeegee." The proper course would be to let such matters flow away along kennels and sewers, but by a sort of antiperistaltic motion they are brought up into our homes, into our very kitchens and bedchambers. Moreover, what the domestic sweeps out of the house the fine lady brings back again upon her clothes and person; thus an ever revolving cycle removes and restores dust or mud poison. No sooner is the dirt of the house swept up and out, than it is brought back in no inconsiderable quantity.

6. We cannot annihilate mud and dust, but by the use of asphalte it can be reduced to its minimum, which indeed, is all that can be done in human affairs. To diminish evils is all that we can do. These are real practical gains, but understood only by observing persons. Few care about dust if it do not quite blind their eyes or make them sneeze. The poison of it they know not, nor do they care. Dust seriously injures the shopkeeper's costly stock, whether of fabrics or of watches or jewels. Whoever has looked at Cheapside and the Poultry in the granite age, looking from the Exchange westward, will have seen in clear dry summer weather an atmosphere of almost impalpable dust like fog. Under asphalte which has been down four years this is much less, indeed it is scarcely visible. Dirt is brought into our streets from distant places by carriages and by foot people quite unavoidably. Let us not through prejudice or interest infest the city with the maximum of this noisome evil, nor by block-pavement of wood, or stone, reticulate the streets with joints or meshes, wherein is collected dirt for redistribution again and again.

7. For the purposes of cleanliness asphalte bears the same relation to wood-blocks that modern crockery or china-ware bear to the ancient wood-trencher. Who would endure the wood-trencher of very doubtful cleanness—suspicious of sand—when he can have a smooth-glazed, absolutely clean plate of earthenware?

Or who would take his ale out of a wooden cup, or a gourd, if he could obtain a beaker of crystal glass, just because wood is less breakable? Better risk the breaking by slipperiness of these smooth cleanest surfaces of these plates or glasses.

8. This is clear, that carriages of all kinds last longer, much longer, when used on asphalte. The tyres, the spokes and naves, the springs and rivets, all that belong to chariot or waggon, are less shaken and not so soon worn up. Hence the money gain must be very considerable as to the greater durability of carriages which are moved over asphalte.

9. There are two evils which do pertain to asphalte to which wood-blocks are not so obnoxious. Horses do not get a sufficient foothold by which they can draw loads over gradients of 50° or 60°. For such places as London bridge and Ludgate hill, blocks of stone or wood must still be used. And why not? Who would insist on the constant use day by day of umbrellas and waterproofs against the contingency of a shower now and then, or of an occasional wet day? Who would keep a drag on the wheels of his carriage for the occasional incident of a steep gradient? The admitted evil of asphalte is its slipperiness in certain but very rare states of weather, such as do not occur once in 100 hours. Surely people honest and in their senses would not abandon the best known pavement because once in 100 hours horses are more liable to fall, and when they are fallen cannot so easily get up. When there is frost after thaw, streets are slippery by reason of ice. People just then must be more careful, and they must drive slowly, and use other appliances. Board-schools, among other things, will soon train up an intelligent race of drivers, or they will not be of much practical use. If people will drive fast without care, they must bear the consequences. Give drivers of public carriages some reward if their horses do not fall, and impose a small fine if they do fall, and an effectual remedy will be found.

10. Further, seeing how much ease and rapidity of transit is now enjoyed by reason of railways, which in the centre of the metropolis are almost continuous, it is not too much to require people, even our merchant princes, to allow ten minutes more in their crossing over the small middle passage, which is only now a few hundred yards from one railway to another. By metropolitan railways they gain time by the hour; let them submit to lose time by the minute for the greatest public improvement. So dangerous is rapid driving over certain central places, that it was once proposed that all carriages should proceed at a walking pace from the Exchange, the corner of Lombard street, Princes street, etc., just to the east end of the Poultry, where seven thronged streets converge. The objection made was fatal; it would interfere too much with the dearly cherished liberties of Englishmen, a liberty to be enjoyed in this case by riding Englishmen, of running down walking Englishmen. It is no refinement to say that by the use of asphalte the brain and head are relieved of the incessant rough vibration caused by transit over stones, and this relief must be beneficial to health. Who would willingly travel London streets paved with any other material but that which causes the least vibration, shake, or jar? This one advantage, fairly estimated, will probably quite weigh against the greater slipping for horses.

11. The remedy against this one evil of asphalte is complete. The contingency, which happens only during one hour in 100 hours, is to be overcome by the abundant use of sand or gravel, or by what is better—water. Water was tried in the city for fourteen days continuously, during a large portion of which long time it was not wanted; but so far as slipping was concerned, it was an effectual preventive. Can we overestimate the folly which rejects so admirable a pavement for a remediable evil, an evil which occurs so rarely?

12. The rival material is wood in blocks. Both are comparatively noiseless; wood is, indeed, more so. Asphalte returns the blow of the horse's foot, though not the noise of the wheel friction. The evils of wood seem to outweigh this one, or at most these two admitted advantages which it has—(*a*) wood is not slippery; (*b*) it is more suitable for gradients.

13. On the adverse side, wood is continuously wet or damp. Wood is porous; it is composed of bundles of fibres. It absorbs and returns wet—foul wet especially. The fibres of the wood are placed

vertically; the upper ends whereof fray out, are abraded, become like painters' brush stumps, and are about as permanently dirty; or they break up like the wooden handle of a chisel which has been struck with an iron hammer, or a wooden mallet when used upon an iron chisel. This fact is beyond all question. Wood is wet or damp more or less, except during continued very dry weather. Its structure is admirably adapted to receive and hold, and then to give off in evaporation very foul matters, which taint the atmosphere and so far injure health. The comparative condition of these rival pavements was well illustrated by King William street and the end of Cannon street, near the railway station, on Saturday afternoon, August 29. After a day of much rain, one was dry and clean, the other was intolerably muddy. Absolute cleanness and dryness is a prime condition; wood is the extreme contrary of this. It is absolutely dirty, and is almost continually damp. The joints of the wood are packed with tar, stones, and mud, and become magazines of poison whether they remain dry or not. Asphalte presents a continuous smooth surface, impervious to wet, while wood pavement, made of reticulated meshes or net-work, collects and holds dirt and damp poison intermixed.

14. There is another evil to which wood pavement is liable, and it should be no further used until more proof is obtained one way or another by the experiment of a severe winter. It is suggested that an accumulation of water will form a substratum, and then by the expansion caused by frost, will dislocate the blocks, and by their uprising will render the surface very uneven, will loosen the blocks themselves, and cause them to eject water from the interstices when the thaw comes. The accumulation of water and its subsequent ejection between the wood interstices is shown already by the present condition of King William street, especially near the statue. We need not wait for the distinct force of frost, for to-day (September 7) there are considerable pools of water (foul water) in various places, which evidently come from below. Here is all the mud of the olden time brought back again. The asphalte close by is quite clean and dry. It is usually dry an hour or two after rain. Moreover, the wood-blocks themselves are already very much worn; the interspaces have become wider and very ragged. Wood will not endure the severe action of waggon-wheels, breaking sharp flint pebbles into saws, knives, and rough wedges. These are fast destroying the wood-pavement. Not another yard of wood should be laid down anywhere until the coming winter has passed; *i. e.*, until April 1, by which time the wood-pavement of King William street will probably be worn into rags, like old felt roofing. If such be its present ragged condition at the end of a most favorable summer, we ought to continue the experiment during the severe trial of the coming winter before extending its use. There is no need of so much hurry, except in the interest of trading parties, who would of course rather get the streets paved with wood before its evils are better known. Mr. Heywood's report, 17th March, 1874, is admirable for logical precision. It sets forth with judicial impartiality the relative good and evil of wood and asphalte. The public is left to judge. While Mr. Heywood seems no partisan, there can be no doubt that his paper leaves the fact established that asphalte is the best pavement known. In concluding these remarks, I beg to observe that I have no interest whatever in the question, other than having an anxious wish that the comparative merits and demerits of the two materials—wood and asphalte—should be candidly examined and proved by observation and experiment.

N. B.—To meet the difficulty respecting gradients it has been ingeniously suggested that broad tramways should be laid for the wheels, and a paved or macadam footway be preserved in the middle of the streets for the horses' foothold.

IRON gives a description of a monument recently erected by the town of Boulogne-sur-Mer to Frédéric Sauvage, who in France is considered to have the largest share of merit in practically applying steam to the screw as a motive power. Sauvage spent his days and fortune in perfecting inventions which brought him no profit; passing finally from a debtors' prison to the madhouse, where he died July 19, 1857.

SAFETY VALVES.

From "The Engineer."

THE Institution of Engineers and Shipbuilders in Scotland deserve great credit for the energetic attempt they have made to settle the vexed questions connected with the construction of marine safety valves, with which our readers can hardly have failed to render themselves familiar. The action of the Board of Trade has long been felt to be oppressive in several matters connected with the construction of marine engines and boilers; and the code of rules laid down by the Board for proportioning and weighting safety valves has been pronounced especially objectionable. For a long period only dead-weighted valves would be passed by the surveyors of the Board; and although this rule has been somewhat relaxed, all valves not loaded with dead weights are still looked upon with doubt and suspicion. The rule that marine safety valves must invariably have a minimum area of half a square inch for every square foot of fire-grate is, however, still rigidly enforced; and this without any regard being had for the peculiarities of the valve, the rate of combustion, or the pressure at which the valve is intended to blow off. If it could have been shown that the area fixed by the Board of Trade was the best that could be adopted, no one would have had reason to complain; but engineers familiar with the subject have long felt that the rule has no solid basis of experimental fact; that it was adopted, in short, simply because the Board of Trade do not know of any better rule, and are too indolent or too careless to endeavor to frame a rule which would be more satisfactory. The Institution of Engineers in Scotland includes among its members a very large number of marine engineers, and questions connected with safety valves have, as a matter of course, been freely and frequently discussed by those gentlemen at the ordinary meetings of the institution. The subject was of vital importance indeed to them, and as little progress could be made with the Board of Trade, it was at last determined that a committee should be appointed to investigate the action of safety valves experimentally, and report on the whole subject to the institution. The committee assembled consisted of Messrs. Walter Brock, James Brownlee, J. L. K. Jamieson, E. Kemp, H. R. Robson, and David Rowan. The report prepared by these gentlemen was laid before the institution about four weeks ago. It has since been printed and issued to the members, and a copy now lies before us. It is a sufficiently interesting paper, and will add to the reputation not only of the institution, but of the three engineers, Messrs. Brownlee, Rowan, and Brock, by whom it has been mainly prepared. The first-mentioned gentleman contributes an able investigation of the laws determining the outflow of steam through orifices; the second, the results of experiments made by him to ascertain the pressure to which steam will rise in a boiler above the load pressure, with valves having half a square inch of surface per foot of grate at different pressures; while Mr. W. Brock supplies the results of experiments which he has made regarding the strength and action of springs as applied to the loading of safety valves. All the experiments were practically new, and were carried out with special apparatus and great care. The report as a whole is so lengthy that we cannot find space to reproduce it entire. Extracts will however be found on another page, and we shall explain here some of its more important results and deductions.

An investigation of the laws of the outflow of steam was obviously required as a basis for any reasoning on the propriety of the Board of Trade rule. It is true that many experiments have already been made to this end by Napier and others, which have shown that Weisbach's theory was erroneous; but the committee wisely determined not to rest content with what had been done by others, and so they constructed special apparatus, which we illustrate in another place, and reinvestigated the subject, with results in the main confirming the views of the late Professor Rankine, as enunciated in "The Engineer" in November and December, 1869. One of the most important conclusions at which the committee arrived is that the Board of Trade rule, specially intended, be it observed,

to apply to the case of boilers working with moderate pressures, is for those pressures radically wrong, while it is only approximately correct for higher pressures such as are carried in the present day. As an illustration of the truth of our assertion, we may cite an example given by the committee. An experimental boiler was fitted up. This boiler had two furnaces, 25 square feet of grate, and 746 square feet of heating surface. It was provided with two safety valves, each $2\frac{7}{8}$ in. diameter, or 6.49 in. area. The total area was thus practically 12.5 in., or half a square inch per foot of grate, and therefore in accordance with the Board of Trade rule. The valves were loaded with dead weights, and were in all respects in conformity with the received regulations. Now the special object of the Board of Trade engineer surveyors in determining the area of safety valves, was to prevent any considerable augmentation of pressure after the valves began to blow. If the regulations do not insure this, they must be regarded as imperfect, if not utterly useless. Now what are the facts? With a load of 5 lbs. on the square inch, these approved valves absolutely allowed the pressure to rise to 13 lbs., or to 160 per cent. more than they ought! It may be urged that this pressure is lower than would be met with in practice, and that the matter is therefore so far of little consequence. But this cannot be said of a pressure of 25 lbs. on the square inch. When loaded to this, the valves permitted the pressure to accumulate to 36 lbs., or, in other words, to 44 per cent. more than they ought; and even with 45 lbs. the pressure accumulated to 52 lbs., being an augmentation of 15.5 per cent. In all cases the lift diminished—as we have often pointed out that it does—as the pressure increased, being for 5 lbs. .325 in.; for 25 lbs., .1425 in.; and for 45 lbs., .097 in. It will thus be seen that the Board of Trade rule really supplies no safeguard whatever, and that boilers fitted with valves passed by the surveyors may be in hourly danger of explosion. We have heard it argued that sea-going engineers cannot be trusted to ease a valve or reduce the formation of steam, and that for this reason care must be taken to supply them with safety valves which will be certain to relieve the boilers no matter how careless or incompetent the engineer in charge may be. With the preceding facts before us, it will be seen that very serious accidents must have occurred over and over again if engineers had not used that common sense with which the Board of Trade refuse to credit them. To show still further how imperfect and insufficient the "half-inch rule" is, we may state that the committee give a table of the proper areas of valves for various pressures from 20 lbs. to 75 lbs. For the first, the required area of valve in the case of a boiler with 25 square feet of grate is 45 square inches, equivalent to two valves each $5\frac{3}{8}$ in. diameter; while at 75 lbs. an area of 12 square inches would suffice, or a little less than that enforced by the half-inch rule. This table is inconclusive, because the committee do not supply any information as to the actual experiments on safety valves from which it was deduced; and it remains to be proved that any safety valve of the ordinary construction, no matter what its area may be, and loaded as the Board of Trade dictate, could prevent a very considerable augmentation of pressure.

As regards the loading of safety valves by springs, we reproduce Mr. Brock's paper, so that we need not further refer to this portion of the report just now. The final conclusions arrived at by the committee we give here in their own words:

"(1) The present practice in this country of constructing safety valves of uniform size for all pressures is incorrect. (2) The valves should be flat-faced, and the breadth of face need not exceed one-twelfth of an inch. (3) The present system of loading valves on marine boilers by direct weight is faulty, and ill adapted for sea-going vessels, a considerable quantity of steam being lost during heavy weather, in consequence of the reduced effect of direct load—the result of the angle or list of the vessel, and also of the inertia of the weight itself, the latter not being self-accommodating at once to the downward movements of the vessel, and, moreover, the impossibility of keeping the valves when so loaded in good working order. (4) That two safety valves be fitted to each marine boiler, one of which should be an easing valve. (5) The dimensions of each of these valves, if of the ordinary construction, should be calculated by the following rule:

$$A = \frac{18 \times G}{P} \text{ or } A = \frac{0.6 \times HS}{P}$$

A = area of valve in square inches.
G = grate surface in square feet.
HS = heating surface in square feet.
P = absolute pressure in lbs. per sq. in.

(6) The committee suggest that only one of the valves may be of the ordinary kind, and proportioned as above, and that it should be the easing valve. The other may be so constructed as to lift one-quarter of its diameter without increase of pressure. Valves of this kind are now in use, and one such valve, if calculated by the following rule, would be of itself sufficient to relieve the boilers:

$$A = \frac{4 \times G}{P} + \text{area of guides of valve,}$$

$$\text{or } A = \frac{.133 \times HS}{P} + \text{area of guides of valve.}$$

This valve should be loaded say 1 lb. per square inch less than the easing valve. (7) As experience in the use of valves of this description is acquired, both may be of this kind, and one of them made to blow into the sea without any increase of pressure, the other to be the easing valve, and loaded 1 lb. per square inch in excess of the working valve. (8) If the heating surface exceeds 30 ft. per foot of grate surface, the size of safety valve is to be determined by the heating surface. (9) As boilers decay from age, it is necessary gradually to reduce the pressure of steam, and the committee recommend that valves should be made of a size to suit the pressure to which the boiler may ultimately be worked when it becomes old. (10) Springs should be adopted for loading safety valves, and they should be direct-acting where practicable. When levers are used, the friction of the joints will cause an extra resistance, and consequent increase of pressure, when the valve is rising, and a loss of steam through diminution of pressure before it will close."

We believe our readers will side with us in regarding these conclusions as temperate; but we are by no means certain that the formulæ given above will be universally accepted as satisfactory. That the report is opposed to the conclusions of the Board of Trade is not the fault of the committee. We have no desire to speak harshly of the action of the Board of Trade as regards safety valves; on the contrary, we believe that the engineers who prepared the objectionable rules did so conscientiously, and in the belief that they would secure the maximum amount of safety. Our complaint is that the officials of a great department have not willingly gone with engineers, and modified their regulations in deference to the wishes of the great body of marine engine builders in this country. If they make rules, they should be prepared to substantiate them, and to prove that they are satisfactory in every respect, and that their sufficiency and completeness is a full equivalent for their arbitrary characteristics. But the Board of Trade have done nothing of the kind. The rules they have prepared are not only empirical, but opposed to well-known laws. It must not be supposed, for example, that it has now been proved for the first time that as the pressure increases the area of a valve may be diminished. That fact has, in its broad sense, long been known. The Institution of Engineers in Scotland have, however, been the first to prove the fact on a sufficiently large and practical scale. If it could be shown that the half-inch rule erred on the right side, and gave too large a valve if anything, then there would be a legitimate excuse for its enforcement; but it actually errs, and that considerably, on the wrong side. Thus, there are many old steamers running now, and carrying passengers daily, the safety valves of which are loaded to but 15 lbs., and in some cases to but 10 lbs. on the inch, these being reduced pressures adopted because the boilers are more or less worn out. Although the furnace plates may be weak and the uptakes patched and honeycombed, the steam-generating powers of such a boiler are not impaired if it has been kept fairly well scaled. A considerable rise of pressure in such weak boilers is a very serious matter indeed. But it is none the less a fact that if such boilers have dead-weight safety valves, and half an inch of area per foot of grate surface, they will be passed by the Board of Trade surveyors—if otherwise all right—as safe; and this in the face of the fact that the pressure may, under these conditions, rise from 10 lbs. to 19 lbs., or 90 per cent., or from 15 lbs. to 25 lbs., or 66 per cent., or possibly to greater pressures than the makers or the Board of Trade ever intended the boilers to carry when quite new.

ETCHING IRON.

From "Iron."

Much time and attention has been devoted by Prof. Kick, of Prague, to the subject of etching iron with acids. His method is not a new one for arriving at a knowledge of the quality of iron or steel, having been used with some success for a long time, but the care with which the professor has conducted his experiments makes them exceedingly valuable.

Some kinds of iron exhibit what is known as the passive state, and are unacted upon by acids until this state has been destroyed by heating. The surfaces thus prepared were inclined to rust very soon. After a series of experiments with nitric, sulphuric, and hydrochloric acids, and etching solutions of copper salts, Prof. Kick found that a mixture of equal parts of hydrochloric acid and water, to which was added a trace of chloride of antimony, was the best etching solution. The chloride of antimony seems to render the iron less inclined to rust, so that, after washing thoroughly in warm water, and applying a coat of Damar varnish, the etched surface may be preserved quite clean.

The smooth surface that is to be etched is surrounded with a ridge of wax an inch high, as is done in etching copper plates, and the acid is poured into the disc thus formed. At a temperature of 55 to 65 deg. Fahr. the action soon begins, as shown by the gas evolved; in winter, the etching is poor. The time required is from one to two hours, but the etching should go on until the texture is visible. Every half hour the acid can be poured off without removing the wax, the carbon rinsed off, and the surface examined. If too much chloride of antimony is added to the acid, a black precipitate will soon form, which can easily be distinguished from the carbon. One drop of chloride of antimony to the quart of acid is sufficient. When the etching is finished, the wax rim is removed, the iron washed first in water containing a little alkali, then in clean water, brushed, dried, and varnished. If in a few hours it begins to rust, the varnish should be removed with turpentine, which will also take off the rust, and then varnish again.

The appearance of different kinds of iron when etched is essentially as follows: Soft or sinewy wrought iron of excellent quality is attacked so equally by the acid, and so little carbon is separated, even after several hours' action, that the surface remains bright and smooth. Fine grained iron acts the same; the surface is still smoother, but a little darker. Coarse grained and cold-short iron is attacked much more violently by acid than the above. In ten minutes, especially with the latter, the surface is black. After thirty minutes a black slime can be washed off, and the surface will remain black in spite of repeated washings, and exhibits numerous little holes. Certain parts of the iron are usually eaten deeper, while others, although black and porous, offer more resistance. By allowing the acid to act for an hour or so, then washing, drying, and polishing with a file, a distinct picture is obtained. Malleable cast iron, we know, rusts more easily than wrought iron, and it is interesting to know that the action of acids is also violent, the surface being attacked very violently. Grey pig-iron acts like steel; the etched surfaces have quite a uniform grey color. In puddled steel the color, after etching and washing, is grey, with quite a uniform shade, and the lines are scarcely visible. Cement steel has a very similar appearance, the lines being very weak. In Bessemer and cast steel the etched surfaces are of a perfectly uniform grey color, with few if any uneven places. The softer the steel the lighter the color.

On etching, the finest hair-like fractures are rendered prominent. A piece of steel, which looked perfect before etching, afterwards exhibited a hair-like fracture throughout its whole length. When different kinds of iron are mixed the acid attacks that for which it has the greater affinity, while the other is less acted upon than if it were alone. Etching is exceedingly valuable to all who deal largely in iron, as it enables them to determine with comparative accuracy the method of preparing the iron, as in the case of rails, &c., as well as the kinds employed.

ENGINEERING PROGRESS.*

From "Engineering."

It is a widely admitted fact, that the enormous impulse given to all industrial pursuits during the present century has been in a large measure due to the subdivision of work and specialization of effort.

A law of development is now recognized by some of the deepest thinkers of the present age, as controlling all growth and progress. The principal feature of this law is the subdivision of work. The development of an animal from a lower to a higher form of life is attributed to the different functions of the body gradually becoming more individual and special in their action. It is suggested that in the lower forms the different functions of respiration, digestion, circulation, etc., are performed by parts which appear to be very slightly different and hardly divided from one another; that, as you progressively examine the ascending forms of life, their differences and divisions become more and more definitely marked, each function being gradually allotted to special parts, which act to the mutual advantage of each other, the digestive organs performing their functions not only for the benefit of themselves, but also for the benefit of the lungs, the heart, the brain, etc., all of which are mutually dependent upon each other, any want of harmony in the action of one being at once felt by the animal which forms the aggregate of all these functions. The higher the organism the greater the organization, such as I have described, until we arrive at man, the greatest and most perfect of God's creatures, whose wondrous functions of body and mind are elaborated, divided, and specialized to an extent far beyond what we see in any of the lower forms of life. Similarly in social life, which is the aggregate of individual life, the most savage tribes are those which do not possess any subdivision of labor, and the highest state of society is that in which the subdivision of labor is carried to the greatest extent.

From these modern theories it would appear that progress in civilization, or growth of any kind, must depend upon the division of labor or specialization of function.

The progress of an art is also subject to the same law; the more you subdivide the processes the simpler each step appears; and the energies of a much greater number of men can be brought to bear upon the various subdivisions. Hence the gigantic development in our arts during this century.

What has been stated generally with regard to the arts is especially true in the case of engineering. Engineering may be described as the art of applying, controlling, and modifying the various forces of nature resident in matter to the mechanical advantage of man.

The early engineers were men who, with large grasp of mind, and proportionate energy, attacked certain problems, and with limited resources succeeded in overcoming the natural difficulties of their enterprises, in such a way as to encourage their successors, with more extensive resources, to still greater efforts. As the number of the profession increased, the great variety of the problems presented to their consideration naturally led to the subdivision of work, and we now find numerous branches of engineering, each branch having its own special followers. By this arrangement, the work in each branch is better done, because each individual brings his mind to bear on a limited range of subjects, leaving other specialties to the efforts of other men. For the benefit of the whole community this subdivision is undoubtedly a great advantage, and every engineer who makes a fresh subdivision of employment confers a boon upon society, and helps forward the development of engineering as an art.

But it must not be hidden from observation that this specializing of effort has, unless closely watched, a narrowing effect upon the individual, due to the small sphere of work in which his intellect is exercised, sacrificing those nobler and wider inquiries of the human mind, which a more extended field of occupation offers.

* Inaugural Address delivered to the Members of the Cleveland Institution of Engineers by the President, Mr. Thomas Wrightson, A. I. C. E., M. I., M. E.

It does not require a very close scrutiny into the engineering works of the present day to verify the fact, that the bulk of such a work is a repetition of previous work which has proved successful, the principal originality being when the engineer has to adapt previous experience to altered conditions. Thus the civil engineer has to take into account variations in climate, geological formation, contour of country, rainfall, and many other conditions, before he can select which of the oft-tried plans of executing any particular work it is expedient to use. The mechanical engineer has a fund of devices from which, according to the exigencies of the case, he may select a particular method of accomplishing his work. So also the mining engineer. From this it might appear that modern engineering does not tend, in the present condition of knowledge, to increase greatly in originality.

Again, commercial success being the great requirement of the ordinary capitalist, originality is to him a secondary consideration, so that he is tempted to discourage the endeavor to introduce anything which has not previously been proved successful.

These considerations make us fear that the future of engineering may be one of less nobility than we have been accustomed to hope for, after reading the achievements of Smeaton, Watt, the Stephensons, Brunel, and others, who originated the methods now so freely resorted to in ordinary practice.

It behooves us, then, to inquire whence the future impetus to the progress of engineering science is likely to be given. According to our definition, we as engineers have to do with the various forces of nature. These forces become perceptible to us through the medium of matter. It is therefore highly necessary that we fully understand the nature of matter and those conditions of matter which we call force.

Sir Isaac Newton immortalized himself by discovering the laws which govern the motion of masses of matter. By his demonstration of the laws of gravitation, a great impulse was given to physical inquiry, an impulse which has been maintained ever since his time, and which has led to marvellous results. The laws of the science of chemistry, as first laid down by the celebrated Dalton, opened a fresh field for physical inquiry, the nature of matter in its atomic condition being attacked. Then came the gradual acceptance of the undulatory theory of molecular motion, which, through the labors of Dr. Young, Chladni, Savart, and others, was accepted as accounting for the phenomena of sound as propagated in air, and then led to the acceptance of the same wave theory as accounting for the propagation of light, heat, and electricity, through the more subtle ethereal medium in which they travel. From the nature of such investigations the progress of the science of molecular physics has been slow, but the physicists of the last 30 years have made rapid strides, and by careful experiments and rigid reasoning, have been able to demonstrate conditions of matter and force which, although unperceived by the senses of sight, hearing, touch, or taste, can yet be visualized in the mind by the seeker after physical truth.

In the study of matter, and the forces to which it is subject, the unity of creation has been impressed upon the student, and every year seems to bring fresh proof of the co-relation of all the known forces of nature. Let us then consider in what way the engineer has been or may be benefited by the study of the molecular forces.

The phenomenon of electricity was, not many years ago, looked upon as an amusing experimental curiosity. Scientific men investigated the subject, studied and classified the various phenomena, until in the fulness of time arose Wheatstone, who utilized this plaything, converting the curious toy into the most wonderful means of communication ever given to the civilized world. Wheatstone, by this application of science, gave to engineering a new department. Telegraphic engineering is now a specialty, which, like all other branches of the art, demands a knowledge of other sciences, many of which had hitherto been considered as quite remote, and dissociated from electric science. Without a knowledge of physical geography, the telegraphic engineer could not undertake the laying down of a submarine cable. He must know much respecting the currents of the ocean, of its depths and temperature. He has to design machinery, and invent pro-

cesses for the proper manufacture and testing of the coils. He has to adapt and design vessels for their transport, with necessary machinery for their safe and effectual laying. This is now an enormous industry for which we have to thank the physicist. Practical success always stimulates further inquiry, and we may be sure that electric science, as studied by such men as Sir William Thomson, Mr. C. W. Siemens, and others, will yield still further results for the benefit of mankind.

Let us now consider the connection which exists between the physical science of chemistry and engineering. If we begin at home, we cannot but see that the mysteries of the blast furnace can only be solved by the aid of chemical science. With the exception of a small number, the ironmasters and blast furnace engineers of this and other districts do not scientifically study the working of their furnaces. Great difference of opinion exists as to the effect of certain conditions, the result of which is, that there are, perhaps, not two "plants" in Cleveland in which the conditions of the construction and the working of the furnaces are the same. Every one seems to have imbibed some peculiar notion, which he supports with a confidence frequently inversely proportionate to his information. A advocates great height and small bosh; B large bosh and moderate height; C pledges himself to a flat bosh; D to a steep one; E considers nothing affects more favorably than a large bell; F will have nothing but a small one; G thinks that an open top gives a better quality than a close one; H quite differs from him; I stakes his reputation on high heats; J condemns them; and K out of another district says the blast should not be heated at all. And we might go through several alphabets to illustrate the number of points upon which in blast furnace practice variety of opinion exists.

As in the search for all physical truth, there are two paths by which we must come to a knowledge of the principles involved in the working of a blast furnace. From the known laws of chemistry much that takes place in the furnace can be deduced; but there is also much that in our present state of knowledge is beyond such inference. To remedy this want of knowledge, reliable and well-authenticated facts are required. These facts, if collected on a scientific plan, not from the plant of a single ironmaster, but from every furnace plant in the district, would, under the searching scrutiny of scientific men, soon lead to the clear perception of laws which are as yet imperfectly understood, though occasionally stumbled against by enterprising gropers after truth. Of one fact we may be sure; that there are laws governing the action of a furnace which cannot be contrary to the truths of physics, and it is only by the aid of the known laws of physics that we can intelligently compare the evidence of facts respecting the working of furnaces, which by an organized scheme of observation may, we venture to hope, some day be collected in this growing district.

Again, as another example, take the important connection between molecular physics and the strength of materials. It seems almost a law of nature that the transmission of any force through the medium of matter involves the change of a portion of that force. As in the transmission of the power of steam through the steam engine a portion is lost as mechanical power, and appears as frictional heat, so in transmitting power through a shaft or chain, a portion of that power appears to go towards producing a molecular change in the atoms of the iron, which, in the course of time, permanently affects the useful qualities of the material. These changes are probably of a chemical and a mechanical nature. How little is really understood by the engineer about this important element in the strength of material, and how many lurking dangers menace the public in consequence! Take for example the phenomenon of seam-rips in the egg-ended boilers so much used in this district. From some tests I have lately been making of the iron cut from the plates of two different boilers which had ripped at the seam, I found that the flame playing at the convex bottom of the boiler had affected the iron at the seam so as to make it cold-short, of small tensile power, and apparently crystalline in its fracture. Further from the seam the iron appeared in all cases less injuriously affected. On annealing pieces of the iron cut from the seams, it was found that the cold-shortness had disappeared, and that the tests both for tensile

power and ductility had been restored to their original condition. The plates in one of these boilers were Staffordshire, and in the other the best make of Cleveland boiler plate. In the former the seam-rip experimented upon had led to an explosion which resulted in the destruction of much property, though happily of no lives. When we consider the hundreds of seam-rips which occur, but are detected in time to avoid explosions, we appreciate the importance of understanding fully, by the study of chemistry and physics, the molecular changes which occur in a boiler plate by the action of fire; as, if this action cannot be neutralized by some process of manufacture, it is important for the engineer to scheme some form of boiler which will be least likely to invite the attack of this insidious enemy.

Let us now glance at another most important investigation of the physicist which has hitherto been unknown to many calling themselves engineers, but which holds out the promise of being the means of making us acquainted with many new facts, as well as of explaining many old ones. I allude to the theory of the conservation of energy. The leading idea of this theory, as worked out by Carnot, Mayer, Helmholtz, Clausius, Joule, Rankine, Sir William Thompson, and a few others, is, that in the universe there is a definite quantity of force of all kinds. These forces are heat, electricity, mechanical and chemical energy, magnetism, etc.; and each of these forces is capable of being converted into any other of them, but the total quantity of force in the universe remains the same. Thus, heat may be converted into mechanical energy, as by the expansion of a heated rod of iron which can be utilized in several ways to do work; or by the production of steam, which works a steam engine, thus producing mechanical work. Chemical energy can also be converted into heat and mechanical work, as when a charge of gunpowder propels a bullet, part of its force going towards the heating of the gun and projectile, and part to the propulsion of the ball. Electricity can also be converted into heat, mechanical power, or chemical energy. Whatever changes take place in the form of energy, the total amount in the universe, by this theory, does not diminish or increase. It may be lost to this world, as by radiation of heat into space the earth becomes cooler; but, as energy, it is still in existence in the universe.

Now this generalization has not been arrived at without minute experimental investigation. Mr. Joule, an eminent physicist of Manchester, twenty-five years ago, made a series of careful experiments to ascertain the relation existing between a given amount of mechanical force and the heat generated by it. The experiments were conducted in the following manner: A certain weight was made to descend a certain number of feet, and in doing so, by means of a silk thread passing over pulleys, to turn a small vertical shaft in a vessel full of water, oil, or mercury. Paddles were fixed to the vertical shaft, so that the power exerted by the weight (with the exception of a measurable proportion lost in friction of pulleys, etc.), went to the production of heat in the liquid through the agitation of the paddles. After numerous experiments, Mr. Joule arrived at the following valuable scientific fact: that a weight of 1 lb. descending through 772 ft., or a weight of 772 lbs. descending through 1 ft., develops mechanical energy which, when converted entirely into heat, will raise the temperature of 1 lb. of water 1 deg. Fahr. This is called Joule's equivalent, and is concisely expressed by Rankine, in his definition of the first law of thermodynamics, as follows: "Heat and mechanical energy are mutually convertible, and heat requires for its production, and produces by its disappearance, mechanical energy in the proportion of 772 foot-pounds for each British thermal unit"—the said thermal unit being the amount of heat required to raise the temperature of 1 lb. of liquid water 1 deg. Fahr., at or near the temperature of the maximum density of water, viz., 39.1 deg. Fahr.

It must be clearly understood that mechanical energy can only be entirely converted into heat when no mechanical work is transmitted. For instance, if, while Mr. Joule's paddles revolved, a portion of the liquid had been raised permanently to a higher level, the heat generated in the liquid would then have been so much less in proportion to the mechanical power so transmitted: or if the whole of the water could be raised such

a height as to reproduce the whole of the energy of the descending weight, there would be no increase of heat in the liquid. For every foot-pound of mechanical energy which is lost, a definite quantity of heat is generated, and when work is performed by the consumption of heat, for each foot-pound of work gained an equivalent of heat disappears. Professor Tyndall performs a beautiful experiment, illustrative of the loss of heat when work is performed. He takes a rigid hollow vessel, and pumps air into it until of a considerable pressure. After allowing it to cool down to the temperature of the room, he places a delicate thermopile (which will show the slightest variation in temperature) in front of a stop-cock on the vessel. On opening the cock the air rushes out of the orifice against the face of the thermopile, which indicates at once a *fall* of temperature. He then takes a pair of bellows, and through a nozzle the same size as in the previous experiment, he presses air by the action of his muscles against the face of the thermopile. This time the pile indicates a *rise* of temperature. Now, why this difference?

The old material theory of heat could not have accounted for it, but the dynamical theory of heat makes the reason obvious. In the case of the rigid vessel, the air itself, by its elasticity, performs work in forcing its way through the aperture at a high velocity. Work exerted means loss of heat, whereas in the case of the bellows the work is not done by the air, but by the arm of the operator, and it is from his muscle that the heat disappears, only to be restored by the fuel, which, in the form of food, it is necessary for him to consume. The heat produced in the case of the bellows is due to the striking of the issuing air against the face of the pile. The same cause produces heat in the case of the first experiment, but the consumption of heat more than counterbalances this. From this experiment, and the reasoning therefrom given us by the physicist, we as engineers can carry the application still further into our practice: we can see now why we are not scalded when we put our hand in a jet of high-pressure steam issuing from a small orifice: also why the hot blast which escapes at the pricking hole of a blast furnace is so much reduced in temperature. We can comprehend the fact that the temperature at the tuyere may be perceptibly less than that in the stove, according to the mechanical energy exerted by the reservoir of air to force the front particles forward. We can also detect the loss of heat and consequent power which results from wire-drawing of steam, and can appreciate the advantage of having direct and large passages for the steam to pass to the engine. The effect of the use of Gifford's Injector upon the temperature of a boiler, and many other phenomena which will suggest themselves to the thoughtful engineer, will be found to bear close relation to this wonderful law of the conservation of force. The problem of the engine builder is to convert heat into mechanical power. He is wonderfully assisted by Nature in this work. In the first place she has laid up a large store of unconsumed carbon, in the shape of coal, which is eminently suitable for the production of heat. She has further provided a boundless store of oxygen in the atmosphere, in a chemically uncombined state, and therefore available for combination with the coal to produce this heat. She has also ordained that the commonest substance on this earth, viz., water, should be the most convenient for using as a medium in converting heat into mechanical force, on account of the low temperature at which it is converted into elastic vapor.

We shall not have time at present to do more than consider whether the study of molecular physics is likely to throw any light upon the important question of raising steam.

The heat produced by combustion is simply the chemical combination of the oxygen of the air with the carbon of the coal. The atoms of the two gases, according to modern theory, rush into chemical combination, and the clashing of these atoms together produces the phenomenon of heat. This heat is not, as was formerly supposed, a substance dwelling in the interstices of matter, but is, as described by Helmholtz, a peculiar shivering motion of the ultimate particles of the heated substance. This atomic motion is transmitted from the heated gas to the plates of the boiler, the atoms of which take up the shivering motion and transmit it to the water inside.

At a conveniently low temperature this

motion of the atoms of water has increased to such an extent that they shake themselves beyond their cohesive force and fly asunder, forming steam.

Now it has been proved by chemical experiment that a pound of the purest coal gives out, when entirely burnt, sufficient heat to raise the temperature of 15,664 lbs. 1 deg. Fahr. The aim of the engineer should be to obtain as large a portion of this heating power as possible; but, with the best results of the most economical boilers, only about 59 per cent. of this power is obtained.

I have taken this proportion from the results of some very exhaustive experiments which have been lately made by M. Lhoest in Belgium, upon the boilers of a 110 horse-power compound steam engine. These are fully reported in the English edition of the *Universal Review of Mining*, for March, 1874, and are well worthy of study. M. Lhoest shows, by a series of observations, that the total effective heat transmitted to the steam was only 59.59 per cent. of the theoretical heating power of the coal as calculated from its components parts. I may say that the above result was from generators somewhat resembling that kind known in England as the elephant boiler, the heating surface being very large, and the steam superheated. The heat of combustion was utilized to such an extent that the temperature of the escaping gases on their entrance into the chimney was only about 350 deg. Fahr. This result was therefore exceptionally favorable, as we may see by referring to Mr. Jeremiah Head's paper on the efficiency of steam engines and boilers, read in 1869 before the members of this Institution, where he shows that we only utilize in this district, in ordinary good practice, 47 per cent. of what is chemically possible. M. Lhoest, from chemical reasoning founded on direct experiment, estimates the remaining 40.4 per cent. of loss to be made up as follows:

	Per cent.
1. Combustible matter lost in the cinders (Charleroi coal used of poor quality)..	9.1
2. Gases escaping through chimney.....	5.43
3. Imperfect combustion.....	5.07
4. Evaporation of 1½ per cent. of water in fuel.....	.12
Radiation, or losses through the brickwork, losses arising from the cleaning of grates and other causes not estimated.....	20.52

It must occur to any close observer that the 20.5 per cent. is a very unsatisfactory item, and that as engineers we ought to endeavor to reduce this amount to a minimum. Apart from the loss by radiation through brickwork, let us consider whether there may not be a loss in the transmission of heat from the gas through the medium of the plate to the water. We are all familiar with the Davy lamp, the principle of which is, that a flame is cut off by the intervention of wire gauze of a suitable mesh. If you take a sheet of fine wire gauze and hold it over a gas jet, you will find the space above the point where the gauze cuts the flame to be quite dark, although the gas is streaming through the meshes; and if you blow out the gas jet, holding the gauze in the same position, you can absolutely light the flame above the gauze, while between the gauze and the nozzle of the gas pipe there is no flame to be seen. Professor Tyndall, in his valuable work "Heat a Mode of Motion," explains this phenomenon as follows: "The molecular motion of the flame is very intense, but its weight is extremely small, and if communicated to a heavy body, the intensity of the motion must fall, as when a two-ounce rifle bullet strikes a 100-pound shot, the motion of the heavy shot is small compared with that of the light bullet."

The intensity of the motion of the flame, being taken up by the molecules of the heavy gauze, is so much lowered that it is insufficient to transmit the necessary heat to produce ignition on the other side of the gauze.

Now, is not this action somewhat analogous to the transmission of heat through a boiler plate? Is there not a loss of heat in passing through the plate? Is not a portion of this molecular motion, in changing its velocity, changed into some other force? I have already alluded to certain molecular changes, which are proved, by testing, to have taken place in the case of the two boilers in Cleveland which ripped at the seams. Here is no doubt the evidence of a change of a portion of heat into another form of energy. This view of the destruction of heat by transmission through the plate of a boiler is probably favored by the result of experiments made on Warsop's system of pumping heated air into a boiler,

to assist the generation of steam. It has been declared by competent authority that there is a positive gain in this process, notwithstanding the mechanical loss which the pumping of the air involves. May not the explanation of this be, that the conveyance of the heat through the thin tubes to the air is so much more complete than that through the thick plates of a boiler to the water, that the mechanical loss in pumping is more than compensated for?

It is further probable that some of the motion of heat under a boiler may pass into other forms of force. The most powerful means ever invented for the production of electric energy is Sir William Armstrong's hydro-electric machine, in which the electricity is collected from a jet of steam issuing from a boiler. This electricity has no doubt been generated by the action of the heat, and according to the theory of the conservation of energy, must have been the cause of an equivalent quantity of heat disappearing. This may account for another portion of the 20.52 per cent. deficit of Monsieur Lhoest.

When we consider that the temperature of the furnace of a boiler is about 2,400 deg. and the water inside the boiler say about 300 deg., it is evident that in a thick plate the molecular vibrations of the iron must be of much greater intensity on the side next the fire than on the side next the water. In fact, the condition of the section of iron lying between the fire and the water must be of a very complicated character, and one which may be studied with good hopes of leading to practical results. At all events we must not say that this proved loss of 20½ per cent. cannot be saved, until we know all the physical conditions of the flame, the plate, the water, and the steam.

We might continue these thoughts to the consideration of the changes occurring in the steam as it produces mechanical energy in the cylinder. We might trace the loss of a portion of this mechanical energy, and identify its exact equivalent in the heat of friction, which is simply the motion of the mass converted into the motion of the atoms at the surface of the rubbing parts. We might further consider the effect of the power of the engine, when allowed to give shocks and twists to different parts of the mechanism, and show that these shocks are in part converted into a form of energy which, as already described, changes the molecular condition of the material.

And do not let us imagine, because these molecular forces do not impress us with the same idea of power as the fall of the avalanche or the sweep of the hurricane, that they are insignificant; far otherwise. In order fully to appreciate this let us examine the mechanical value of the changes that occur in the atoms of 1 lb. of water passing through its various forms of gas, vapor, liquid and solid. Water is composed of eight parts by weight of oxygen, and one part of hydrogen, and is the result of their combustion. In the first stage we have the free atoms of oxygen and hydrogen, which attract each other and clash together in combustion. It has been proved by experiment, that the heat generated in burning one-ninth of a pound of hydrogen, with its equivalent of eight-ninths of a pound of oxygen, producing 1 pound of aqueous vapor, is sufficient to raise 5,833 lbs., or about 2½ tons of water, 1 deg. Fahr. We have seen, by Joule's experiments, that each pound of water raised 1 deg. in temperature is equivalent in mechanical force to 772 lbs. raised 1 ft. high. The combination of the oxygen and hydrogen to produce 1 lb. of aqueous vapor will therefore produce such a heat as is equivalent to raising 5,833 lbs. $\times$ 772 = 4½ million lbs., or 2,010 tons, 1 ft. high. Professor Tyndall remarks on this amazing fact, "that it was no overstatement which affirmed that the force of gravity as exerted near the earth is almost a vanishing quantity, in comparison with these molecular forces. The distances which separate the atoms before combination are so small as to be utterly immeasurable; still it is in passing over these distances that the atoms acquire a velocity sufficient to cause them to clash with the tremendous energy indicated above." But amazing as this force is, we have not yet finished with our history of a pound of water. The atoms of the aqueous vapor now fall together to produce liquid water. The mechanical value of this act is equivalent to the raising of 333 tons 1 ft. high.

The next change is from the liquid state to the solid form of ice, the mechanical value of which act is equal to 49 tons raised 1 ft.

The total mechanical value of these three acts of one single pound of water, in the change from gas to vapor, from vapor to liquid, and from liquid to ice, is therefore equivalent to a weight of 1 ton crashing down a height of 2,392 ft.

We are tempted to retire into scepticism of these wonderful facts, accustomed as we are to judge of the magnitude of force by the effect it produces upon our senses, but the deeper we look below the surface of nature, the more shall we find that her most wonderful powers are hidden from our coarser perceptions, and only reveal themselves by the light of reason to the earnest seeker after physical truth.

Time has not permitted me to give more than a very few illustrations of the connection between physical science and engineering practice, but in all these illustrations, we see that changes in force are from motion of mass to motion of atoms, and from motion of atoms back to motion of mass. The motion of mass which we see in this world is insignificant compared with the inner motion of atoms which we cannot see. Atomic motion is the great store of force from which we as engineers must derive most of our power, and if our art is the converting of this enormous store of energy to the use of man, does it not seem to be our duty, and should it not be our highest pleasure, to study closely the co-relation of these various forms of energy?

If we, as engineers, would only study and endeavor to apply the recent discoveries in physics to our several specialties of practice, there would be little fear of the contracting effects of specializing the various branches of our profession to which I alluded in the early part of this address.

It is to the science of molecular physics that engineering must look for its future development. Amazing as the achievements of the fathers of engineering have been, we cannot study the exquisite laws which govern the different forms of energy without feeling that there are equal triumphs in store for the future, and that the true line of engineering progress must lie through those fields of investigation which surround the temple consecrated to the study of the physical sciences.

THE BESSEMER SALOON "GYROSCOPIC" APPARATUS.

From "The Nautical Magazine."

SINCE the philosophical toy the gyroscope was first brought under the notice of the public, proposals or suggestions have frequently been made that the seeming persistency with which it endeavored to maintain its disc in the same plane of rotation might be applied effectively to lessen the oscillations of cabins, gun platforms, and observation stages at sea.

The most important of these attempts is in the magnificent Bessemer saloon steamer, now nearly ready for sea. The original intention was to manœuvre the suspended saloon, by working or regulating controlling valves by the hand of a watchful attendant. An experimental cabin on this system, we are told, was erected on Mr. Bessemer's grounds, at Denmark Hill. In this experiment, said to have been very successful in its results, the motion of the cabin was controlled by hydraulic gear, the opening or closing of the valves, governing the admission of the water to or its release from the hydraulic cylinders, being effected by a man within the cabin; this man being guided in his movements by a spirit-level placed in front of him. The experience with this experimental apparatus showed, it is said, that it was possible for a man, by exercising constant attention, to control the movements of the swinging cabin in the manner desired; but in the practical application of the suspended cabin to a sea going vessel, it has been deemed to be strongly desirable to dispense with the necessity for constant vigilance on the part of an attendant; and hence Mr. Bessemer has been led to design the "gyroscopic" apparatus which forms the subject of this notice. In our description of this apparatus we are availing ourselves of a full account of it which appeared in *Engineering* for October 9. It is there stated that "a heavy disc or wheel made to revolve rapidly in any given plane tends always to remain revolving in that plane, and it can only

have the direction of its action of rotation changed by the application of considerable force, the amount of this force depending upon the weight of the revolving body and its speed of rotation."

Here we have the word "action," evidently a misprint for "axis." As it reads, the statement is perfectly true, for it would, indeed, require a very considerable force to reverse the "action of rotation," of a 2-foot wheel running at a speed of six miles per minute; but such a statement is, in this instance, quite irrelevant. In Mr. Bessemer's specification of his patent, he says, "I avail myself of that property of matter which tends to maintain the axis of all rapidly revolving bodies continuously in the same plane, as exemplified by the rotation of a rifled shot, and still more clearly in the toy instrument known as the 'gyroscope.'"

Here again we must correct the language; the word "plane" must, we think, be a clerical error for the word "line." If we are wrong, we shall be glad, in a future article, to reconsider it as it stands. In what follows we have, however, in considering these two quotations, proceeded as if they were intended to stand as we have corrected them.

Availing himself of this remarkable "property of matter," Mr. Bessemer has constructed a monster "gyroscope" (?) 2 feet in diameter, with a rim 4 inches square, and the intention is to run it by water turbine power at 5,000 revolutions per minute, if necessary. The expectation of the inventor is that the steadying effect of this rotative energy will be sufficient to prevent the instrument from participating to any serious extent in the oscillation of the saloon; the frame of the fly-wheel being suspended upon trunnions in a line with the axis on which the saloon is suspended. The machine is connected, by suitable rods, with the valve of the hydraulic controlling cylinders; the valve is an equilibrium valve, so that there will be, as far as possible, no resistance applied to cause the steadying "gyroscopic" wheel to deviate from the horizontal.

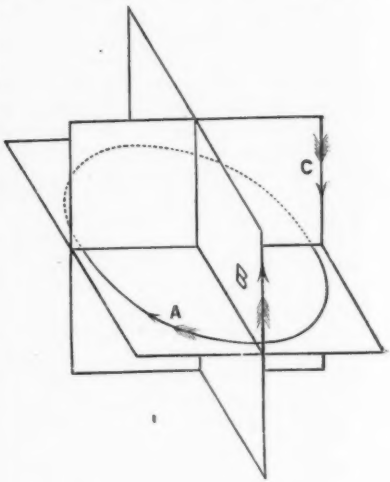
New designs for passenger steamers, involving untried theories, so far as these may affect safety, are placed, by the express action of the Legislature, and, as we think, very properly so placed, under the immediate supervision of the Board of Trade. We do not know whether the owners of the Bessemer ship have submitted their plans to the Board of Trade, including therein their proposals and plans for this controlling apparatus. We presume, however, that the whole subject is under consideration by the Marine Department, and that, as is usual in such cases, a practical trial at sea will be required, before they give a certificate that the ship and all in her are fit and safe for the conveyance of passengers. But we have no hesitation at all in predicting that if the plans published in *Engineering*, on the 9th of October last, are authentic and correct, the general public have reason to be thankful that there is a Board of Trade, for we feel sure that a passenger certificate cannot be granted to the Bessemer ship. The apparatus is, however, so nearly complete, that there will, we imagine, be little if any advantage gained by interfering officially before the inspection services of the surveyors are applied for to test the apparatus at sea.

The first thing we have to call attention to in connection with the design published in *Engineering* is the expressed intention of running a 2-feet wheel at 5,000 revolutions per minute. Bourne says that, to provide against the effect of centrifugal force, railway wheels of malleable iron "can scarcely be considered safe at a speed even considerably under 150 miles an hour." The speed proposed for the Bessemer wheel is 360 miles an hour, and there is no provision shown to prevent even that velocity being greatly exceeded. This wheel is, we understand, to run in the saloon; there should be some way of testing it, as boilers are proved to double their working strain before the Board of Trade can pass it as safe for passengers. As no doubt the wheel is of the very best material, and as some satisfactory test may be devised and accepted, it is probable that this difficulty can be got over; but, even if the "gyroscopic" wheel can be run with perfect safety at any required speed, what then? Nothing! There would be no more steadying effect produced than if the material composing the machine were carried as pig-iron at the same height in the ship. The "property of matter" of which the inventor thinks he has availed himself, does not exist; for, as a fact, the

plane of rotation of a heavy revolving disc can have angular motion imparted to it just as easily as can the plane of a stationary disc. That increased persistency of plane is induced by velocity of rotation is only an assertion, and although it is an assertion made by most of our standard authors as an assertion of a fact, and although the assertion has, we believe, never before been disputed, it has really no foundation; and it certainly will not be proved by the beautiful contrivance on board the Bessemer ship.

We sympathize sincerely with the projectors of the Bessemer saloon steamer, and we sympathize the more because we trace their mistake to standard scientific literature treating on this subject. Mr. J. McFarlane Gray, about the year 1855, attended a *conversazione* at the Philosophical Institution in Newcastle. He has informed us that he there saw, for the first time, the phenomena of the gyroscope, the large gyroscope belonging to Sir William Armstrong being on exhibition that night. He was so taken by it, that he stood beside it the whole of the evening, and the impression of that exhibition has never been effaced from his mind. He was not satisfied with the explanation given to him by the attendant, and, fortunately, he did not give up the investigation until he had completely solved all the paradoxes presented by the gyroscope. Through him, principally, other officers of the Board of Trade have become familiar with the engineering principles involved in the gyroscope. It is not the first time the subject has been officially before the officers of the Department. Our readers will probably not have forgotten that some years ago, Mr. Arthur Rigg, at the Institution of Naval Architects, asserted that the fly-wheels in Mr. Holt's engines would be a source of danger to the shafting, by reason of gyroscopic action interfering with the freedom of pitching. As there were then under construction similar engines with fly-wheels larger than any before in use, it became the duty of the surveyors to calculate the strain that would be due to the greatest probable velocities of revolution and of pitching, and they then found the moment of strain to be equal to the weight of the wheel, acting with a leverage of only one foot. This result was stated by Mr. McFarlane Gray at the meeting of the Institution of Mechanical Engineers, in the following year. That was, so far as we are aware, the first example of direct calculation of gyroscopic effect as an engineering quantity. Following out the line of reasoning as Mr. McF. Gray has stated it to us with reference to the Bessemer saloon, the seeming persistency of direction of plane manifested by the gyroscope, and supposed to operate in the flight of a rifled shot, is due to a condition that is essential to that machine, and which obtains also in the case of the rifle shot, but is by construction excluded from Bessemer's apparatus.

A gyroscope may be defined to be a



machine exhibiting a rapidly-rotating fly wheel, the axis of which has angular motion in a surface that is approximately the surface of a cone. To produce gyroscopic resistance to change of direction of plane, in a given plane, the disc must be permitted, at the same time, to tilt itself in a direction transversely to the direction in which that effort to change the plane is applied. That is, let there be three planes, A, B, C, intersecting each other at right angles, and a rotating fly-wheel with its plane of rotation in A and its axis at the intersection of B C, and, only to fix the idea, suppose the plane A to be horizontal, the plane B to be vertical, edge on to the observer, and

C to be the plane of the diagram, as in the figure.

If, while the fly-wheel rotates in the direction A, a force be applied to tilt the plane of the wheel in the direction B, a couple of equal and opposite pressures will be produced, acting in the plane C, tending to tilt the wheel at the same time in the direction C. If the plane of the wheel be permitted to move in the direction of that couple—viz., C—that motion will similarly create a couple of equal and opposite pressures acting in the plane B in the opposite direction to B. It is the misconception of this reaction that has given rise to the fallacy about increase of inertia of plane, produced by velocity of rotation. In this fallacy it is always overlooked that the resistance is associated with a motion transverse to that resistance. When the transverse motion is prevented, as in the Bessemer design, the side pressures due to velocity, acting as a couple in the plane C, being equal and opposite, just cancel each other, and when the wheel is tilted in the direction B, there will be no *work* done by the couple acting in the plane C, and consequently there will be no increase of resistance to motion in the direction B, by the velocity of rotation, and the apparatus, when so restrained, is not a gyroscope, and the material of which it is composed will act when the vessel rolls only, just as if it were so much dead weight carried as ballast. Further, when the vessel pitches the action of the apparatus will be seen to its full effect, for it will then operate to violently apply in the way to produce rolling all the power that has been provided to resist rolling, and thereby, without at all reducing the *pitching* of the saloon, add a most violent and destructive transverse motion, probably striking the stops at each side each time the vessel pitches.

Such a machine will prove to be, if it is ever tried at sea, a powerful oscillation producer, of no use when the vessel *rolls* only, and rocking the saloon to destruction when the vessel *pitches*.

We understand that Mr. McF. Gray has protected himself by patent in respect to the possible application of gyroscopic apparatus to Bessemer saloons, &c. His practical knowledge of rotatory dynamics, and his well-known inventive talent, may probably enable him to complete what Mr. Bessemer has so pluckily begun. The exact formulas, expressing the pressures, moments, and motions of the gyroscope under all conditions, are of a very simple character, and will probably now be brought before some learned society.

In amelioration of our remarks, it is proper to state that the Bessemer plans are quite in accordance with accepted engineering principles, and if Mr. McF. Gray is right—as we are satisfied he is—the circumstance of the Bessemer saloon will make his exposition of this fallacy the more striking, and cause it to be so notorious that a similar mistake can never occur again.

EFFICIENCY OF FURNACES BURNING WET FUEL.

As Determined by Experiments on a Large Scale.

BY PROFESSOR R. H. THURSTON.

From "The Transactions of the American Society of Civil Engineers."

(Concluded.)

30. The minute inaccuracy of the results thus obtained, which is due to changes of the specific heat of water, and of metal, under varying temperatures, is of no practical importance. As the vessel containing the water heated was of wood in each case, the usual correction for heating the vessel when metallic becomes of no importance also, and the weight of the thermometer being insignificant in comparison with that of the water, that correction is unnecessary. This method is of great value as a last resort, in absence of other good heat-measuring appliances.

31. The second furnace which was experimented upon by the writer was of the form known as the "Crockett." This form of furnace is shown in Fig. 2, and that here described was of the same general form as that illustrated, differing principally in its arrangement of bridge walls.

In this example two furnaces were con-

structed side by side, each having a grate surface of 4 × 6 feet, the total grate area of both being 48 square feet.

The grates were of cast iron, of ordinary form, set so closely that none of the wet fuel could fall through into the ash-pit. It was stated that it was not intended that the charred fuel should fall through and burn in the ash pit.

During this trial, however, more or less burning tan was continually falling into the ash-pit and burning there. This, undoubtedly, assisted in some degree in the desiccation of the wet fuel, by direct radiation of heat, and by heating the entering air as it passed over this bed of hot coals. To this extent the furnace resembled in its action the Thompson furnace, already described.

Above the grates a brick arch was turned, as shown, against which the products of combustion impinged and the heat radiated from the burning fuel on the grate, keeping this arch at a high perature, it assisted the process of desiccation of wet fuel, when first thrown in, by strongly radiating upon it the heat thus stored up while the fires were most intense. From the furnace the gases passed directly into the flues beneath the boiler.

32. The tan, wet from the leach, was charged into the furnaces through the doors in the front, as in all usual forms of furnace, and the process of "firing" differed but little from that usual with thin fires, where coal is used. The fuel was thrown in at intervals of between 5 and 8 minutes, the furnace-man taking care, first, to fill all holes in the burning mass, and, next, covering the whole with a very evenly distributed and very thin layer of fresh fuel. This fresh charge was quickly dried by the heat of the burning fuel, over which it was spread, and by the heat radiated from the hot furnace arch above it, and, taking fire, burned freely. No special effort seemed to be made to obtain "alternation" in working the furnace, but the irregularity with which the fuel burned at different parts of the grate did, perhaps, secure something of this effect.

33. The fuel was measured in the leach, as in the previous case, and about a half leach, measuring 4½ cords, was burned during the trial, between 8 o'clock A.M. and 6 o'clock P.M. The actual working time was 9 hours, the work being stopped from 12 M. to 1 P.M.

34. The tan bark burned was hemlock, mixed with some oak. It looked like a better material than that used in the other trial. It was more cleanly ground, seemed less "soggy," and had a much better color.

35. The boilers used here were two in number. One was an old-fashioned "Cornish" boiler, 4 feet in diameter, and 18 feet long, with one 24-inch flue. The second was 6 feet in diameter, with four 18-inch flues; the total length was 15 feet. The gases from the furnace were led under the boilers, and then, with a double return through the boiler flues, to the chimney. The total heating surface, reckoned as before, was very closely 700 square feet.

36. The flues were stated to have been so long in use without cleaning, that the draught was somewhat impeded by the accumulation of ashes beneath the boilers, and that the rapidity of combustion was somewhat lessened. The two trials are, therefore, both to be taken as representing less than the maximum capacity of the furnaces.

37. The trial was made by a somewhat similar method to that adopted in the one already described. The quality of steam was determined similarly. The water was measured differently. In this case the capacity of the feed-pump exceeded several times the requirements of the boiler, and the only absolutely reliable means of determining the quantity of fuel seemed to be to measure every pound going to the pump, thus evading the uncertainty attending any attempt to secure regularity in the action of the latter.

38. A barrel was fitted to the suction-pipe of the pump, and an employee of the Mechanical Laboratory of the Stevens Institute of Technology was stationed with a hose to fill it with water, when it became empty, and to keep an account of the number of barrels used, while an employee of the proprietors of the tannery, stationed at the pump, checked the account. All of the water fed into the boilers during the trial was thus measured, and at the close of the trial the barrel was taken out, filled on the scales, and the weight of its contents determined.

39. There was no opening into the chimney flue through which the escaping

gases could be reached, and their temperature was not determined.

40. The amount of smoke issuing from the chimney of this furnace was considerably greater than was observed at the preceding trial, indicating that the Thompson Furnace secured a somewhat more perfect combustion than the Crockett.

41. The results of this trial gave the following data:

Total number of cords of tan burned	4.5
" weight of water fed to boilers	28 509 pounds.
Temperature of feed-water entering boilers (estimated)	160° Fahr.

Temperature of water observed in determining "priming":

	Initial.	Final.	Range.
1st observation	68°	118°	50°
2d "	70°	118°	48°
3d "	76°	126°	50°
4th "	96°	124°	48°

Length of trial.....9 hours.

42. Estimating the priming as before, we obtain from the several observations, which were made with the steam pressure, per gauge, 55, 50, 45, and 60 pounds, respectively, x=9.02, x=8.07, x=9.12, and x=8.55, and the per centage of priming, 9.8, 19.3, 8.8, 14.5 per cent. The mean of all observations gives the average percentage of priming at 13.1 per cent., and indicates that the steam issuing from the boiler carried in suspension 15 per cent. of its own weight of unevaporated water.

43. We determine the total heat from the fuel thus:

Steam produced.	28 509x0.869=24 774.32 pounds.
Water primed...	28 509x0.131= 3 734.68 "

The mean pressure of steam during the trial was 50.44 pounds per square inch, and its temperature 298° Fahr. Its total heat at 298° from 0° was 1 204.8 units per pound. Then we have

Total heat, per pound of steam	1 204.8—160=1 044.8
Total heat per pound of water	298—160=138, and
Total heat transferred from fuel to steam.	25 884 209.54 units.
Total heat transferred from fuel to water...	515 385.84 " and hence
Total heat transferred from fuel to feed.	26 399 595.38 units.
Total heat per cord of wet tan	6 866 576.75 "
Equivalent evaporation per cord, water at 212°	7 103.84 pounds.
Equivalent weight of coal per cord of tan..	710.38 "

44. A sample of the fuel used in this trial was sealed up, as before, and was similarly weighed at the Stevens Institute of Technology, dried in the air one week, and its loss of moisture determined.

This sample contained 55 per cent. of water, and 45 per cent. ligneous material. The weight of the tan in the leach was judged to be practically the same as in the preceding trial, and the equivalent evaporation per pound is $\frac{7\ 103\ 84}{2\ 233.56} = 3.19$ plus the water held by the fuel, say 1.22, or 4.41 pounds.

45. Comparing the quantities of heat actually utilized by transfer from the fuel to the boiler, we obtain as the measure of the actual comparative efficiencies of the two furnaces 4.24 ÷ 3.19=1.33, the Thompson excelling the Crockett 33 per cent. A number of circumstances combine to make the actual difference somewhat greater than the record here indicates, but this result may probably be taken to represent practically the relative economical standing of the two furnaces.

46. Experiments on dry pine wood, made by Prof. Johnson during his extended and invaluable examination of American coals,* for the U. S. Navy, furnish a standard of comparison which will be useful here. One cord of well-seasoned yellow pine wood weighed 2,689.2 pounds—10 per cent. more than a cord of thoroughly air-dried spent tan bark—and one cubic foot weighed 21 pounds. Experiments on evaporative power showed, as a mean result, an effect equivalent to the evaporation of 4.69 pounds of water from 212°, under atmospheric pressure, per pound of wood consumed, the temperature of chimney flue being 315 2°, and the wood burning at the rate of 15.87 pounds per square foot of grate per hour, under a boiler having a ratio of heating to grate surface of 26.83 to 1.

47. Comparing this result, as a standard, with the evaporation obtained in the two wet fuel furnaces, per pound of fuel, exclusive of water, we get for the Thompson furnace $\frac{5.68}{4.69} = 1.21$, and for the Crockett, $\frac{4.41}{4.69} = 0.94$. The Thompson fur-

* Report to the Navy Department on American Coals. By Walter R. Johnson. Washington, 1844, pp. 546-550.

nace is thus seen to have given a better result per pound of ligneous combustible when burning wet tan than was obtained in the ordinary steam-boiler furnace, burning seasoned yellow pine, this superiority reaching 21 per cent. The Crockett furnace had 94 per cent. of the efficiency of the common wood-burning steam-boiler furnace.

48. The relative efficiency of fuel, comparing wet tan with dry wood, by weight, the former containing between 55 and 60 per cent. of water, becomes

$$\frac{4.24}{4.69} \times 100 = 90.40 \text{ per cent.},$$

each fuel being consumed under the most favorable conditions shown above, and equal weight of ligneous fuel being taken for comparison.

A cord of dry yellow pine, as per experiments of Prof. Johnson, evaporated 12,618.3 pounds of water. A cord of wet spent tan, burned in the Thompson furnace was equivalent to $\frac{9\,459.2}{12\,618.3} = 0.75$ cord of dry wood. One cord of wet spent tan, burned in the Crockett furnace, was equivalent to $\frac{7\,103.84}{12\,618.3} = 0.56$ cord of dry yellow pine.

49. A cord of dry yellow pine is approximately equal in heating power to 0.6 of a ton of coal, and, conversely, the ton of good coal is equal in calorific power to 1.66 cord of soft wood. An average pound of dry wood is theoretically capable of evaporating 6.66 pounds of water from and at 212.° A pound of good anthracite, similarly, should evaporate 13.5 pounds of water.

The "absolute efficiencies" of coal and wood, under the conditions already described in the several cases mentioned, are as follows: coal, 70 per cent.; wood, in the Crockett furnace, 66 per cent., in the ordinary steam-boiler furnace, 70 per cent., and in the Thompson furnace, 85 per cent.—reckoning the evaporation of the moisture in the fuel. Excluding this moisture, the percentages become respectively 70, 48, 70, and 64.

50. The data obtained at these trials are sufficiently complete to furnish a basis upon which to construct the theory of action of each furnace, and to give approximate determinations of quantities which are of importance in that connection, and of interest in their bearing upon practical deductions. The most important points are the temperatures of furnace and of chimney flue, the quantity of air supplied, and the effect of variations of area of heating surface of boilers.

51. An approximate determination of the temperature of furnace can be made, in this case, in the following manner:

The fuel used at this furnace, as taken from the leach, contained more than one-half its weight of water. In handling, it lost some of this moisture. When thrown upon the top of the furnace, and before it was thrown upon the fire, it, by its non-conducting property, prevented to some extent loss of heat, and such heat as was absorbed by it was usefully employed in evaporating its moisture. The quantity of water thus lost before entering the furnace may be estimated approximately at about 1 per cent. in handling and 3 per cent. at the furnace. Box, in his "Treatise on Heat," gives the total loss of temperature by conduction and radiation, in a fire-brick furnace, as 10 per cent. Here, several long ovens were placed side by side, and the principal loss was that from the top. Very little could take place laterally, and no heat could pass downward.

The total loss here may be taken as $2\frac{1}{2}$ per cent., which would so change the composition of the wet fuel as to leave it with 3 per cent. less water, making it about 45 per cent. combustible and 55 per cent. water.

Taking the available heat per pound of the dry portion at 6 480 thermal units, each pound of wet fuel yields 2 916 units of heat. Of this, 531.6 are absorbed in the evaporation of the 55 per cent. of water, leaving 2 384.4 units to raise the temperature of the products of combustion. Of these there are, as a minimum, 3.7 pounds having a mean specific heat of about 0.287.

The elevation of temperature is therefore 0 245.3°, and adding the mean temperature of the atmosphere, 74°, the mean temperature of furnace, assuming no dilution with unused air and no losses, would have been about 2 320°. Losing about $2\frac{1}{4}$ per cent., the temperature becomes 2 260°.

The temperature of chimney flue was found by experiment to have been 544°. The furnace gases were therefore cooled

2 260°—544°=1 716° by the loss of the heat given up to the boiler. This is equivalent to $1\,716 \times 0.287 = 492.5$ heat units per pound of gas, and to 4 049.4 units per pound of ligneous material in the fuel.

The "equivalent evaporation" from and at 212°, is $4\,049.4 \div 966.6 = 4.18$ pounds of water. The actual evaporation was equivalent to 4.24 pounds, and the difference—less than one per cent.—represents losses and errors of approximation.

52. The actual existing temperature of furnace can be thus estimated: the available heat per pound of fuel, excluding water, has been given at 2 916 thermal units. Of this $\frac{531.6}{2\,916} = 0.182$ was not useful in raising the temperature of either the furnace or the chimney. Hence, of all heat liberated, 1.00—0.182=0.818* was efficient in elevating the temperature of furnace, and 0.37—0.182=0.188 was effective in producing the observed temperature, 544°, of chimney. Then, since the same quantity of gas passes at both places, the temperature of furnace was

$$\left(\frac{0.818}{0.188} \times 470\right) + 74° = 2\,118.5°.$$

To this is to be added the slight loss of temperature, *en route* between furnace and chimney, by conduction and radiation.

53. The air supply of the Thompson furnace is unusually restricted, and has already been noted.

Instead of an ash-pit with a front entirely open, we find here closed ash-pit doors, and no other opening for the passage of air than the comparatively small orifices in the registers with which the doors are fitted. The usual amount of air supplied in furnaces burning coal is generally given as about twice the theoretically required quantity, giving a temperature of about 2 400°. In exceptional cases the air supply falls as low as one and a half times the theoretically required amount, the temperature reaching about 3 000°. In such cases it sometimes happens that the grates are melted down, cast-iron melting at between 2 700° and 2 800°.

In the Thompson furnace, with an ash-pit fire, this is very likely to take place with iron grates, and the inventor was therefore driven to the use of fire-brick grates. The mean temperature of the products of combustion is, however, lower, notwithstanding the restricted air supply, in consequence of the presence of moisture.

The quantity of air supplied is calculated as follows: the difference between the theoretical and the actual temperature of furnace, as above estimated, is 2 260°—2 118°=142°, corresponding to $142 \times 0.287 = 40.75$ thermal units per pound of gas, or $40.75 \times 3.7 = 150.8$ units per pound wet fuel, and $150.8 \div 0.45 = 335.1$ units per pound of wood, which heat was distributed through the air diluting the products of combustion.

This latter amount is sufficient to heat $(335.1 \div 0.238) \div 2\,044 = 0.69$ pounds of air from the temperature of the external air, 74°, to 2 118°. The theoretically required quantity of air, per pound of wood, is 6 pounds; hence, the products of combustion at the Thompson furnace were diluted with 12 per cent. of air: this is one-fourth that of ordinary practice with coal fires.

54. The temperature of chimney flue not being known, the estimates of temperature of furnace and of air supply cannot be so satisfactorily determined for the Crockett furnace. The following may, in the opinion of the writer, be taken as a fair approximation.

The composition of the fuel, in this case, was slightly changed in handling, between the leach and the furnace, as before. Lying in front of the furnace also, a small amount of drying must have occurred by radiated heat. Taking the total amount of both influences as producing an alteration of 2 per cent. in the composition of the fuel, it becomes 52 per cent. water and 48 per cent. dry wood.

55. The theoretical temperature of furnace gases, estimated as before, is reduced largely in this case, by the air of dilution. The fuel was burned at the rate of about 20 pounds per square foot of grate per hour, and the weight of carbon, the only valuable heat-producing element, was 5 pounds per square foot of grate per hour. The bulky character of the fuel compelled the opening of the doors, in charging the furnace, about once in seven or eight minutes. The fire burned some-

* Assuming 6 480 units as the heating power of the tan when dried, the efficiency of this furnace becomes 0.63, and 0.37 of the total heat of the fuel passes off by the chimney.

what irregularly into holes, allowing an unusual amount of air to pass up unutilized.

In ordinary practice, with anthracite coal fires, the fuel burns, with such draught as was found at the Crockett furnace, at the rate of about 10 pounds carbon per square foot of grate per hour. The doors are opened about once in fifteen or twenty minutes, and the air supply is about 240 pounds per square foot of grate surface per hour.

56. The air supply at the Crockett furnace was apparently in excess of that just given, by a large amount. Neglecting this excess, and calculating the temperature of the furnace as if the air supply were the same as with coal, the following results are obtained:

Available heat per pound wet tan..	3 110.4	units.
Rendered latent by evaporating 52 per cent. water	503.6	"
Effective in elevating temperature..	2 606.8	"

This was distributed through 12.5 pounds of gaseous products of combustion, of a mean specific heat, 0.25. The elevation of temperature was therefore 832.8°, and, adding the mean temperature of external air, we obtain for the average temperature of gases escaping from the furnace, including cold air streaming through the furnace doors and the holes in the fire, 919.3°, or about 100° above the temperature at which combustible gases can take fire.

Taking the air supply as possibly at times as low as that considered the minimum with ordinary coal fires, 180 pounds per square foot of grate per hour, where burning fuel with sluggish draught, the temperature of furnace at such times becomes 1 150.3°.

57. The temperature of chimney flue may be readily estimated for these conditions. Referring the performance of this furnace, like the preceding, to "dry wood" as a standard, its efficiency is 47 per cent. Hence 53 per cent. of the heat obtainable from the fuel passes off by the chimney. The loss of heat by the escape of unburned carbon, in the form of smoke, although more than at the other furnace, was not probably sufficient to be here taken into account. The following are the estimates:

Available heat per pound of wet tan	3 110.4	units.
Passing up chimney, 53 per cent...	1 648.5	"
" " latent in vapor	503.6	"
" " elevating temperature	1 144.9	"

This was distributed throughout 12.52 pounds of gas where the usual supply of air was maintained, and through 9.64 pounds in the case of less free supply, supposed possible at times.

The heat per pound of gas amounts to 91.4 units for the first case, elevating the temperature $91.4 \div 0.25 = 365.6°$ above that of the atmosphere, or to 452°.

Under the other supposed conditions, the elevation of temperature of chimney becomes 467.7°.

To secure an economy at this furnace equal to that obtained at the Thompson furnace, it would be necessary to reduce the quantity of heat carried off by the chimney gases in the proportion of 53 to 37.

One-third of this heat is latent in the vapor of water, and no part of that can be secured. The requisite reduction of temperature of gases to effect this economy is thus exaggerated; and it would be necessary, were such a thing possible, to bring down the temperature of chimney to between 140° and 160°, to a temperature 160° or 140° below that of the boilers itself, or to less than one-fourth that required for most efficient draught.

58. In determining the precise value of two competing sets of apparatus, as generators of heat, it is necessary first to obtain from each its best performance in producing heat, and then to provide means of absorbing and utilizing that heat with equal thoroughness in both cases.

The proper area of heating surface of boilers will therefore vary with each case. The same area, where the furnaces themselves differ considerably, may in the one case allow a waste of heat, while in the other it may reduce the temperature of gases so far as to compel the adoption of a "mechanical draught." In the cases here considered, the area of heating surface was fortunately very nicely adapted, in each instance, to the requirements of the case. In both examples, the temperature of chimney flue is found to be somewhat below that required for most efficient draught, but was not far different in the two cases, the less economical furnace having the economical advantage of such difference as did exist.

The trial, therefore, exhibits very fairly the intrinsic values of these two furnaces as heat-generating apparatus, and of these

two radically different methods of working them as taken apart from the efficiency of heat-absorbing or heat-utilizing contrivances.

59. The importance of high temperature of furnace is strikingly and beautifully illustrated by these results. The two furnaces develop practically the same amount of heat from the fuel, but the one distributes it through a large volume of gases at low temperature, sending a considerable proportion of it up the chimney, while the other raises a small volume of gas to a much higher temperature, making it more available to the extent of 33 per cent., and finally, even then, sending up the chimney gases of higher temperature than the first.

The abstract *efficiency of the furnace*, in any ordinary case, is represented by the formula—

$$e^1 = \frac{t_1 - t_2}{t_1 - t_3} = \frac{T_1 - T_2}{T_1 - T_3}.$$

Where e^1 represents the efficiency and t_1 and t_2 are the absolute temperatures at which the heat is generated, and at which wasted heat is discharged, and t_3 that of the external air, T_1, T_2, T_3, are temperatures on the Fahrenheit scale.

In these cases

$$e^1 = \frac{2\,118° - 544°\ \text{F.}}{2\,118° - 74} = 0.77.$$

$$e^{11} = \frac{919° - 452°}{919° - 86.5} = 0.56.$$

60. These values do not represent the *efficiency of the fuel*, including the vaporization of water contained within itself. In these cases the heat lost, as latent in vaporization, before the generation of these temperatures, is to be deducted to give the total efficiencies of the fuel, which thus are found to have the values of 0.77 (1—0.182) = 0.'63 and 0.56 (1—0.175) =0.46.

The experimental determinations were 0.64 and 0.48, if referred to seasoned wood, and 0.63 and 0.47 when referred, as here, to dry wood of a calorific value of 6 480 heat units.

To make the values of e comparable with the standard already assumed for *final absolute efficiency*, per experiment, it is necesary to add 9 per cent. to the first values of e, in each case, in order to credit the fuel with the heat used in the vaporization of its water, and with the heat carried by the vapor up the chimney.

Thus the values 0.77+0.09=0.86, and 0.56+0.09=0.65 are deduced. These ratios, by experimental determinations, were 0.87 and 0.67. The correspondence of these figures with those just deduced theoretically is a remarkably conclusive evidence of the accuracy of the estimated temperature and of the fact that the difference of efficiency found by trial is due to such difference of temperature. The accordance is unusually precise.

61. Rankine has given a formula* for determining the efficiency of fuel in ordinary steam boiler practice, where the ratio of the area of heating surface, and of fuel burned per hour, to the square foot of grate surface, is known:

$$\frac{e^1}{e} = \frac{B\,S}{S + A\,F},$$

in which $\frac{e^1}{e}$ is the quantity called above e^1, A and B are constants, and F and S are the ratio of fuel burned per hour to the square foot of grate, and the ratio of area of heating surface to grate area.

For the cases here considered $A = 0.5$, and $B = 0.92$, $S = 8.5$ for the Thompson, and 14.5 for the Crockett furnace, $F = 1.38$, and 5.3: $\frac{F}{S}$ becomes 0.13 and 0.36, and the value of $\frac{e^1}{e}$ is, for the Thompson, 0.859, and for the Crockett furnace 0.776.

Were this formula applicable to these cases, the experimental determinations of efficiency should coincide with these, but they are 0.64 and 0.48. This difference is a consequence of the facts that the fuel used in these furnaces was wet, and that the large proportion of heat absorbed by the water was so much abstracted from the efficiency of the fuel. Thus the absolute values are reduced.

They differ, also, in consequence of the important fact exhibited in the preceding paragraphs, that the temperature of furnace differs in each case (and in the case of the Crockett furnace immensely), from the temperature, 2 400°, given by Rankine as the mean temperature of furnaces to which his formula is adapted. This changes relative values.

* "Steam Engines and Prime Movers," p. 292, § 4.

The value 0.859, for the Thompson furnace, is almost precisely that obtained by experiment—"including water in fuel," 0.86—as it should be, since the temperature of that furnace, 2 118°, is not far different from that of the ordinary coal fire. The value, 0.776, for the Crockett furnace differs greatly from that formed by experiment—"including water in fuel," 0.67—as would be expected in consequence of the exceptionally low temperature of that furnace.

The difference between these two theoretical values, $0.859 - 0.776 = 0.083$, would represent approximately the loss of total absolute efficiency that might be expected were the case one of ordinary practice, and were the Thompson furnace supplied with boilers of as small a ratio of heating surface to fuel consumed, $\frac{F}{S}$ as the Crockett furnace actually had.

The difference which would really be produced would be less in consequence of a circumstance peculiar to that example, of which the influence has not been noticed by writers on this branch of the theory of engineering.

62. The rate of conduction of heat from the furnace gases to the heating surfaces with which they are in contact varies, in some not well determined ratio, with the difference of temperature. It may be represented approximately, according to experiments of Charles Wye Williams,* and judging from the analysis of M. Paul Havrez,† by a hyperbolic curve of which the equation is $x\,y = A$, y representing the evaporation for a unit of area of a tube at a distance x from the furnace.

$U = B \log x$ is the equation of total evaporation.

When the volume of gas is the same, as in cases to which the formula of Rankine applies, the constants in these equations are the same, and his formula gives a remarkably satisfactory approximation. Where, as in the Thompson furnace, the restriction of the air supply causes a comparatively slow movement of gases along the heating surface, the value of that portion nearest the fire becomes enhanced, leaving the furthest portions of less efficiency.

* "On the Steam Generating Power of Marine and Locomotive Boilers."—London, 1864.

† "Evaporisation decroisante en Progression, Geometrique dans les Chaudieres."—Revue Industrielle, 1874.

The effect of reducing the air supply nearly one-half would, therefore, be to actually reduce greatly the amount of the theoretical loss, 0.08, just given. The real loss would be somewhere between this 8 per cent. and the smaller differences noticed between the theoretical estimates of efficiency of fuel and the actual differences shown by experiment. This latter consideration may, perhaps, be taken as a proof that this difference of efficiency due to such a change of heating surface, would amount to approximately 2 per cent. Were more steam wanted, this would be at once sacrificed at the Thompson furnace, to bring the temperature of chimney up to that, 645°, which would give most efficient draught.

63. At the Crockett furnace, the effect of the exceptionally low temperature of furnace is to equalize the value of heating surface; and the considerable velocity of the gaseous current, which is a consequence of the unusually great volume of air passing through the furnace, increases this effect. The nearer surface is inefficient, and the most distant portions of the heating surface are therefore proportionally much more efficient than in the preceding case.

Extension of surface is, however, precluded by the fact that the temperature of escaping gases would fall still further below that required for effective draught, and, as already indicated, were it possible to operate the furnace at all, this temperature would become one-half the temperature of the boiler, were so much heat abstracted as to give an efficiency of fuel equal to that obtained in the other furnace. Heat would then pass from the boiler to the gas at those portions of its surface furthest from the fire, and the draught could only be maintained by means of special "blowing" apparatus. This is another fact illustrating the importance of high temperature of furnace in the attainment of high furnace efficiency.

64. The following table presents the results of the above investigation in a concise form, in which it may be found very useful for reference.

65. Both of these furnaces were introduced about twenty years ago, and the first is in somewhat extensive use. No experimental determination of their actual relative efficiencies has ever been made

Results of Trials of Furnaces burning Wet Spent Tan Bark, August, 1874.

Kind of Furnace.	Fuel.	Percentage.		Total weights pounds.			Steam.	Priming.	Percentages.		British thermal units per cord of tan.	Apparent evaporation.				Actual evaporation.		Ratio of air supply to theoretical.
		Water.	Combustible.	Fuel.	Combustible.	Feed.			Priming to feed.	Priming to steam.		Per cord fuel.	Per pound combustible.	Per sq. foot grate per hour.	Per sq. foot heat surface per hour.	Per lb. of fuel.	Per lb. combustible.	
Thompson	Tan	59	41	44945	17198.41	73125	68393.8	4731.2	6.47	6.92	9143321.4	9596.75	4.25	23.7	2.81	1.3	3.98	1.12
Crockett	Tan	55	45	22336	10051.20	28509	24774.32	3734.68	13.1	15.	6866576.75	6335.33	2.83	65.9	4.52	.....	2.46	8.
Ordinary steam boiler	Pine wood	....	80	.....	2360.50	.....	.....	.....	.....	.....	.....	10891.26	4.05	61.5	2.29	4.05	4.03	.....
Ordinary steam boiler	Anthracite coal	....	91	.....	.....	.....	.....	.....	.....	6.	.....	.....	8.75	95.	3.00	7.35	8.75	2.

Kind of Furnace.	Approximate estimate mean temperature of furnace gas, Fahrenheit.		Equivalent evaporation per 212° F. per lb., including water in fuel.	Equivalent evaporation from 212° F. per lb., excluding water in fuel.	Relative efficiency, excluding water in fuel—Crockett =1.	Relative efficiency, excluding water in fuel—wood=1.	Relative efficiency, including in account water in fuel — Crockett=1.	Relative efficiency, including water in fuel—wood=1.	Absolute efficiencies, water in the fuel			
									excluded		included, dry wood as standard	
	Furnace.	Flue.							Standard of 6385 units.	Dry wood of 6480 units.	of 6385 units.	of 6480 units.
Thompson	2118°	544°	5.68	4.24	1.33	0.90	1.29	1.21	0.64	0.63	0.85	0.86
Crockett	919°	452°	4.41	3.19	1.00	0.68	1.00	0.94	0.48	0.47	0.66	0.67
Ordinary steam boiler	.....	.....	4.69	4.69	1.47	1.00	1.06	1.00	0.70	0.70	0.70	0.70
Ordinary steam boiler	2400°	700°	10.50	10.50	3.28	2.23	2.37	2.23	0.70	0.70	0.70	0.70

before, so far as the writer is aware, which has enabled their theory to be worked out. The determination of their theory, as here given, has greatly interested him, and will, perhaps, prove as interesting to the profession. It may be found of value, in view of the many important applications which are daily being made of the various kinds of wet fuel.

The temperatures, as given, may be somewhat below actual temperatures where they are determined from the composition of fuel, as the calculations are made on the assumption that all vapors issuing from the fuel are raised to the mean temperature estimated. The real fact is, that they are expelled while the temperature of issuing gases is reduced by their presence, and they therefore do not abstract as much heat as is debited to them in the calculation.

During those intervals of time which elapse between the drying of one charge and the introduction of the next, the temperature of furnace rises to that due to the combustion of dry fuel. The results, as given, are probably, however, practically and sufficiently correct.

ON SOME DIFFERENCES BETWEEN BRITISH AND AMERICAN ARCHITECTURAL PRACTICE.*

By WILLIAM FOGERTY, F. R. I., B. A.

A RESIDENCE of over two years in the United States, during which I have visited the principal cities and become acquainted with many of the leading members of the architectural profession, having previously spent the greater part of my life in the study and practice of architecture in the United Kingdom, has brought fully before my mind many important differences in the systems of practice prevalent in the two countries, the consideration of which may not be unworthy the attention of this Institute. The differences I refer to are not such as relate to modes of construction, employment of material, or artistic style, but have reference to the business relations between architects, clients, and contractors, rates of remuneration, measures of responsibility, and such like, constituting what may be called the economic aspects of the profession, apart from the scientific or æsthetic, and as such may be conceived as of great importance in themselves, and as presenting peculiar advantages for comparison, with a view to the adoption in one country of what has proved advantageous in the other, or the rejection in one of what has been found objectionable in the other.

I am very far from assuming, as one would suppose to be the case with many who have written on this great country and its institutions, that because of the youth of the nation, therefore it must be content to remain behind in many things, or in other words, that it is not as yet sufficiently developed or educated to avail itself of every improvement, general or special, which has been proved and found desirable in Europe. I have heard this idea broached as often by native Americans as by Europeans, but from whoever it originates, I disclaim all sympathy with it. On the contrary, I am convinced that there is no invention or improvement in the whole compass of modern civilization for which this country is not ready, and which, if it be really an improvement, will not meet with recognition proportioned to its value. The experience of the past, short though it be, fully bears me out in this view. So far from being disposed to remain behind Europe in the practice of any art, science, or business, the disposition of the American people is, if I judge it rightly, to advance beyond the older portion of the world; and in pursuance of this noble ambition, as every unprejudiced person must admit, they have often enough succeeded; for it is easy to point to many things that are far better contrived, ordered, and settled here than in Europe. Nor are such things to be looked for outside the limits of the architectural profession. Many improvements, both in design and construction, are to be found in American buildings, for which, as yet, we look in vain in Europe. And even if we confine ourselves to the limited aspect of the profession contemplated by the present paper, we find that in some particulars the condition of the profession

* Read at meeting of the N. Y. Chapter of the American Institute of Architects, Tuesday, Dec. 1, 1874.

is rather better here than there. For instance, the frantic and disgraceful struggles called architectural competitions are neither so numerous nor yet so humiliating as in England. Every time a church, school, or other quasi-public building is to be erected, a score or two of architects are not found ready and willing, as in England, to prepare elaborate and costly designs for it, on the bare chance of one of them getting the job and earning thereby a few hundred pounds or thousand dollars. Architects' assistants and draughtsmen are also somewhat better paid here than in England, though not as much in proportion as mechanics or other skilled helps. But when we have mentioned these two more favorable conditions, we have nearly exhausted all that exist, though not, let me hope, all that will soon be developed, when the really advantageous position which ought to be occupied by the architectural profession, in so great and growing a country, is better understood.

Certainly, if we compare the amounts expended on buildings in this country with the corresponding amounts expended in England, the advantage would seem to be enormously on the side of the American architects. I have carefully observed the amount of work doing in several of the great cities, and am well satisfied that there is at least as much actual building doing in the United States as in the United Kingdom, but that the amount of money expended in this amount of building is on the average about three times as great. The difference is not so noticeable in small works, and the general use of wood in country houses tends to lessen it; but on the other hand, the use of brick, stone, and iron has become very general of late, and when we come to deal with structures where these materials are employed, the disproportion is enormous. I have little hesitation in saying that substantial buildings cost, on the average, five times as much here as in England. For instance, a first class city church, bank, newspaper, or insurance office, that would cost $500,000 here, could be well built for £20,000 there. Nor does this enormous difference of cost seem to have any effect in lessening the number of costly buildings to be erected. The American public seems determined to have great and noble buildings, at whatever cost—a resolve which should be at the same time honorable to the nation and advantageous to the architects. I know of only one building now in progress, in the whole British Empire, on which the expenditure, after years of discussion, has been authorized to reach a million of pounds, and yet I could name half a dozen buildings in progress in the United States on which the expenditure is likely to reach three and even four millions of pounds. Whatever, therefore, may be the relative condition of the profession in the two countries, the public that has to be served is enormously more lavish in its expenditure on this side than on the other. Yet I fear that, whoever may reap the benefit, but a very small and undue share of this lavish expenditure must find its way into the pockets of the architects.

For when we come to compare notes as to the actual condition of the profession in each country, the advantage, apart from the two particulars previously noted, would seem to be altogether on the British side. First, the profession is much more numerous there than here. About 150 architects' names appear in the New York business directory for a city of one million inhabitants, while London gives about 1,000 to a population of three-and-a-half millions. Even this comparison should be adjusted, for the London and New York architects are not so much dependent on their respective cities as on the country at large, and I need scarcely say that the population of the United States is considerably greater than that of the British Isles. And, leaving numbers out of the question, let us compare the incomes realized as far as they can be judged. The profession of architecture is not a particularly lucrative one anywhere, but nevertheless, I think among its members indications of well-being are more manifest in England than in America. The leaders of the profession there, who are generally noted by having the somewhat doubtful honor of knighthood conferred upon them, have also commonly realized adequate fortunes or incomes, and, in a fair number of cases, have sat in Parliament and become chairmen or directors of banks, railways, and insurance companies. And the men in good practice, next to them, generally manage to keep up as good establish-

ments as the men of same rank in other liberal professions. I must say I have heard very few cases of fortunes made by architects in America.

Among the numerous biographies of self-made men, which form so large a part of the popular literature with which "young America" is regaled, I find merchants, manufacturers, lawyers, doctors, contractors, engineers, builders, store and hotel keepers in abundance, who, in greater numbers than in any other country, have risen from nothing to affluence, but rarely if ever have I found mention of an architect of whom the same can be said. The only remarkable case I can call to mind is that of the late John Kellum, whom, as I am informed, this Institute would not admit to its membership. It can hardly be doubted, I think, that in this country architects are not much appreciated. Those of them who occupy public positions, even though charged with the direction of enormous and costly structures, which cannot be rivalled in these respects in Europe, are yet paid salaries which, when the high price of living is considered, amount positively to a bare subsistence. The architect of the United States Treasury in Washington, directing an expenditure of from ten to twenty millions of dollars annually, and conducting what is undoubtedly the largest architectural business in the world, receives the magnificent sum of $4,000 a year. The State of New York is a little more liberal to the architect of the new Capitol—one of the greatest architectural works the world has ever seen—and allows him $10,000. Compare these with the salary of the architect of the City of London, who has only to attend to the buildings undertaken by the Corporation of that one city, and receives £3,000 a year, besides a liberal extra allowance whenever special arrangements have to be made for the reception of a Sultan, Shah, or Emperor. Although Sir Charles Barry considered himself shabbily treated, he received 3½ per cent. on about two millions of pounds for the new Houses of Parliament, and the vigorous remonstrances made by the profession on that occasion secured that in all future works of like magnitude, such as the Government offices and the Law Courts, the regular rate of five per cent. has been adhered to. A still more significant example of the slight esteem in which architects are held here is to be found in the notices of public buildings by the press. Rarely if ever is the architect's name to be found in any of these. The committee, contractors, superintendent — anybody is deemed worthy of special mention but the architect, whose share of the work is not considered worth mentioning. Intelligent Americans, both at home and abroad, are not slow to boast of the great structures to be found in this country, such as the Capitol and other public buildings at Washington, but not one in a hundred seems to know who were the architects of these great works, or if he does happen to know, to think anything remarkable about them as having exhibited genius, skill, or taste of which the country might be proud. Not so the merest ragamuffin in the streets of Florence or Vienna, who knows all about Michael Angelo and Palladio; or the youngest schoolboy in London, who knows St. Paul's and the London churches as the works of Sir Christopher Wren. The material elements of a building, its dimensions, the amount of granite or marble used in it, and especially the number of millions of dollars it has cost, are considerations to which the American mind is fully alive; but the mental or artistic element, the brain work involved in the design, and particularly the man who supplied this brain work, are matters apparently regarded with supreme contempt and indifference.

And yet this takes place in a country by no means ungrateful to her great men or humbler intellectual laborers in other fields. The names of the founders of the Republic, of the signers of the Declaration of Independence, of the generals, admirals, and statesmen who have adorned its history are as much honored here as are those of the corresponding men of other countries. American authors do not reap their full pecuniary reward, chiefly because of the absence of an international copyright, but receive their full share of honor at all events. American painters, sculptors, and musicians have no cause to complain of want of appreciation by their countrymen, nor will either the incomes earned by or the consideration accorded to the members of the legal

and medical professions suffer by comparison with the same in England.* Architects seem to stand almost alone in the experience of neglect and even contumely in a country where their services ought to be more in request and more highly valued than in any other.

A very little observation and comparison will show that architects are much more extensively employed in the old country than in the new. Scarcely any building is undertaken in the United Kingdom without one. A sensible man there would think as soon of going to law without a lawyer as of building without an architect. In this country, however, nothing is more common than to see large and costly structures erected without any, the business being done or rather usurped by some boss mason or other contractor who succeeds too often in persuading the proprietor that he can do better than any architect, which would certainly be true if his own profit and interest were the only matters to be considered.

The Rev. Dr. Osgood, a well-known and warm friend of the profession, in the address which he gave to the New York Chapter about a year ago, admitted pretty much what I have stated above, when he alluded to there being "trouble between the American public and the architects." And as one of the means he prescribed to remove this trouble was that architects should use their pens more, I will endeavor so to use mine as to trace out some of the causes which bring the profession in this country into disrepute, and by comparison with the older country, to point out some of the means by which its status may be improved.

The chief element in the want of appreciation shown by the American public towards architects is to be found in the ignorance which prevails as to what the proper functions, responsibilities, and remuneration of architects really are or ought to be. A general idea of course prevails that architects "draw plans," but beyond this the most profound ignorance will be found to prevail. If we can only succeed in removing this ignorance, a vast deal will be done towards removing the evils which follow from it.

I have already alluded to the disgracefully keen struggles which take place in England over every public building thrown open to competition; but this after all is only one instance of the overcrowding in every branch of business which prevails there, and proves that at any rate the position of architect to any public building is something worth striving after, and it really is so, because once appointed to that position, the duties, responsibilities, and emoluments are understood and admitted as a matter of course. Here, on the contrary, once a design is selected, the architect has to enter on a series of discussions as to what further he is to do in reference to it; whether he is only to furnish the plans, or whether he is also to superintend, and in what way, and at what rates; if there is to be a superintendent besides the architect, and if so, whether he is to act over or under the architect. If it be settled that the architect is to be paid a commission, and the rate of that be settled also, a third question arises also as to what amount it is to be charged upon; whether upon the whole, half, or two-thirds of the cost of the work. That such questions can and do arise indicates, as above stated, a deplorable amount of ignorance on the part of the building public; but it indicates more; namely, a vast deal of neglect and irregular practice on the part of the profession. It ought surely be the business of the architects, individually or collectively, to enlighten the public on all these questions; for if not, who else is to do it? A proper code or system of practice is needed, towards which the Institute has certainly made some approach, but this will be of no avail so long as the profession generally do not adhere to it in practice. The functions, powers, responsibilities, and charges of architects need first to be thoroughly understood and agreed on among themselves, next to be made known to the public in every possible way, and thirdly to be fully and honestly acted up to by the profession. When these three conditions are fully complied with, it will be seen whether the public will not accord a larger amount of respect to the profession than ever it has done hitherto.

* Professor Erichsen, one of the most eminent surgeons in England, who has recently visited this country, and lectured on the condition of the medical profession in it, is of opinion that that profession enjoys a higher degree of social status and consideration in the United States than in any other country.

In considering such a code or system of practice, the profession in this country ought to be possessed of a great advantage in having all the experience of the old country to guide them. Up to the present it would seem as if this Institute had been very much disposed to follow that example, for I observe the brief scale of charges issued by it agrees in the main with that of the British Institute. It however differs in being much briefer and less definite, the former of which would be an advantage if it did not involve the latter. Brevity is highly desirable if it be not attained at the expense of clearness. Now the scale of charges of the American Institute makes no mention either of a surveyor or superintendent (or clerk of works), thereby ignoring or leaving in doubt two most important points in architectural practice; namely, accurate estimating and proper supervision. Now, my observation during the period referred to above has led me very strongly to form the opinion that the total neglect of one of these points, and the irregular manner in which the other is performed, are among the most powerful causes that have contributed to make the profession at large to enjoy so little of the confidence of the American public; and I therefore propose to consider these subjects in detail more fully further on.

If the American architects could succeed in getting the same rates of charges generally adopted here as in England, the profession ought certainly be a very lucrative one, for, as already observed, the cost of building is so much greater. To take the examples already quoted, a church or other first-class building for which the architect would receive £1,000 in the old country, he would get $25,000, or nearly £5,000, for here. And yet he would have no more to do in one case than in the other. To be sure he would have to pay his assistants a little higher, perhaps twice as much as the same class of men receive in the old country, but this is almost the whole difference. The wonder is, then, that with such a scale of charges apparently in general use, the architectural is not the most lucrative profession in the country. But a little further inquiry will soon show that the attempt to establish the same rate of charges here as in England has not succeeded, and that, as a general thing, no such rates are paid unless on frame or other small buildings, where the outlay would not be much greater than on similar buildings in England. And I think the American public can hardly be blamed for hesitating to pay New York architects four or five times the actual money for the same services as is paid to London men, merely because it amounts to the same rate per cent. And I question whether this high rate being so publicly put forward, although privately departed from, does not frighten the same public from having anything to say to architects at all, and thereby defeats its own object. Certainly it has been noticed more than once, that the architects who have habitually worked under that rate have done well, but that those who have persisted in adhering to it have done but indifferently or worse. I respectfully suggest, therefore, that unless it is to include more than what is ordinarily included in England, the five per cent. may be too high a rate for an architect's services on such buildings as those referred to, and might possibly, with advantage both to the profession and the public, be reduced.

It is commonly urged in defence of the attempt to set up the same rates of charge here as in England, that the cost of living is so much greater here than there as to justify it. But this is not by any means clear. House rent, clothing, and a few other items cost more, but the difference is not such as to justify architects in asking so very much more for their services than their English brethren get. The medical and legal professions do not ask four or five times the fees of their British confreres. It need scarcely be observed that the judges, cabinet ministers, and other high officials, get much less than the corresponding functionaries in the old country. But supposing the statement as to the cost of living were admitted, then the means adopted to meet the increased expense are very unfortunate, for the effect, as above pointed out, is greatly to limit and circumscribe the employment of architects, and cause them to realize much less incomes on the whole than are attained by the members of the same profession in the old country.

It may, however, be worth considering whether it is not better to keep to the

time-honored rate, but to make it include, not only all that is included in England, but also some things that in England are considered additional matters, although incidental to an architect's employment. And I am not clear but that this was the idea of the original framers of the American scale. At least, such is the plain meaning of it as it stands. The first clause reads, "In full professional services (including superintendence) five per cent. on the cost of the work." Passing over the possibility of an architect's having to prepare several designs for the same work, for which the English scale specially provides an extra charge, and for which the American one makes no provision, let us inquire what would any intelligent client understand by this? Would not he at any rate understand that the architect was bound to superintend fully? and would not he justly consider that a demand on the part of the architect for a local superintendent, to be paid by the client, in addition to what he pays the architect, was highly unreasonable? And yet I have heard and read loud complaints from American architects because clients will take this view. I think it a great matter of regret that there should be any misunderstanding on such an important subject, and that it issues either in the architects attempting to carry on their works without competent local superintendents, or that the clients will insist on having such, but make a deduction from the architect's fees on that account, and too often transfer the confidence which should be given to the architect to the superintendent instead. In fact, instead of working harmoniously, as do the English architects and their local superintendents, or "clerks of works," as they are called, the American architects and superintendents are commonly to be found arrayed in hostility against each other. And I hope I will be pardoned for saying that I fear the chief blame for this unsatisfactory state of things rests with the profession. For surely the idea that the architects themselves, by making occasional visits, can fully and properly superintend works of any consequence, whether in their immediate neighborhood or perhaps miles away, is downright preposterous. Most clients regard it as such; and, if there be no other superintendent than the architect, expect, and with reason, to see him at the building every day. Of course the client is disappointed in this expectation, and finds that what he and his architect meant respectively by "full professional services (including superintendence)" were two different things. Unless he is satisfied to have his work scamped, he will insist on a local superintendent forthwith, on account of whom the architect's fees are reduced, and who, feeling that the architect would have done without him if he could, too often begins to do his best to oust the architect and supplant him in the confidence of the employer. This is clearly a most objectionable state of things, and can only be remedied in one or the other of two ways; viz., either by the architects honestly undertaking to do by deputy what they cannot do in person, and providing competent local superintendents, appointed and paid by themselves (which I believe they could well afford to do if they get the five per cent.), or by a clear distinction being drawn between the general superintendence, which the architect can give himself, and the close and constant supervision by a local superintendent, and by the client being at once advised that the first is all that he can expect from his architect, the second he must pay for in addition. This latter is, as is well known, the English system, and is clearly enough stated in the English scale; and if it be thought desirable to have the same adopted here, it should also be stated in the American scale. I doubt very much, however, that the American public at large will ever agree to pay architects five per cent. and pay superintendents in addition; and I would recommend in preference, to keep to the existing scale, but act on it in its full meaning, and let the architects of all important works provide competent local superintendents paid by themselves and responsible directly to them. This would go far to gain the confidence of the clients, and reconcile them to the payment of the five per cent., and I am informed has been the practice of some of the most successful men, both in New York and Boston. Anything almost would be better than to have noble designs murdered in their execution for want of proper supervision, or to have architects ousted from a most important part of their business by the rivalry of

hostile superintendents, thereby reducing them to the level of mere draughtsmen.

There can scarcely be a more dangerous rock for the architectural profession to split on than this; for not alone is the superintendence of their buildings likely to be taken out of their hands, but also the selection of contractors and control of building operations generally. In this respect the practice here contrasts disadvantageously with that of the old country. There the whole business of getting tenders and arranging contracts is done under the architect's direction, it being a settled principle that none but contractors with whom he is satisfied shall be employed. Here, I regret to observe, selections of the same kind are made without any reference to the architect, and often enough, in consequence, contracts for large works are awarded to scoundrels destitute alike of principle, capital, or credit, from whom the architect may as well expect to get good work as to bring any other clean thing out of an unclean. And it may easily be observed that no matter how little the architect may have had to do with the selection of the contractor, and how honestly he may have endeavored to compel the proper execution of the work, he is held fully responsible, both legally and otherwise, for whatever failings or defects may be found to exist in it.

The next important point of difference between English and American practice has reference to the preparation of estimates, and is of the utmost consequence as affecting the credit of the profession. I think there can be but little doubt but that the American public has little or no faith in architects' estimates. The report of Governor Dix to the Legislature of New York contained most severe strictures on the profession in this respect, and whether fully justified or not, his remarks were extensively echoed by the press, and I am not aware that any satisfactory answer or explanation was ever given on the part of the profession. And if we look into the matter and compare notes, we find that this is unquestionably a neglected matter by American architects. The manner in which estimates or bids for works are obtained in chief cities of the United States is still the same as it was in England fifty years ago, and may lawfully be characterized as unsystematic, wasteful, and inaccurate. It does not seem to be usual to have any calculations made on the part of the owner or architect as to the amount of work requisite to carry out a design, or the prices that work is likely to cost, until actual bids or tenders are required. Architects' estimates, therefore, are very seldom made at all, and what pass for them would be more properly described as architects' guesses, not being the result of calculation. When tenders are asked for, accordingly, neither the architect or owner has commonly any but a very hazy idea as to their probable amount, and the extent to which that may be affected by any particular item in the design or specification. The drawings and specification are placed before a number of contractors, who commonly take up a deal of the time of the architect and his assistants, as well as a deal of his office room, while engaged in overhauling them, and making out their calculations, and unless the architect has his drawings lithographed, so as to be able to supply each contractor with a copy, a vast deal of delay and inconvenience occurs in lending out the drawings to one after the other. When the bids or tenders come in, they only appear ordinarily as lump sums, for the contractors are very chary of allowing their detailed calculations to be seen, and with good reason, for any that have yet come under my notice exhibit the most surprising discrepancies and absurdities, and it is therefore easy to understand why they should be so sedulously kept out of view.

Before reviewing other defects in this system I may first observe that it is evident a large waste of labor is involved in the fact that each contractor has to calculate the quantities of work for himself, a business which might just as well be done by one for all, and a very complex matter if properly done, but which of course may be slurred over or jumped at if men prefer to do so. The fact that contractors, are found willing to incur all this unnecessary trouble is no defence for the waste it involves. At present it is the only means they have of obtaining contracts, and must be submitted to, but of course it must be paid for in some way and come out of somebody's pocket. Architects may fancy it is no affair of theirs, because the contractors are willing to put up with it, but this principle, if

generally acted on throughout the world, would forbid all improvements by which waste is stayed or economy effected. A steamship, railroad, or telegraph company, for instance, which would neglect any means by which waste could be stayed, merely because the public or shareholders, not having any other resource, had to put up with the result whether on the rates or dividends, would be guilty of gross unfaithfulness either to the shareholders or public, possibly to both. If the architects are to be really what they are nominally, the "master-builders," it is their duty in the interest of the building public to make such arrangements as will prevent waste of all kinds, and thereby popularize as much as possible the business in which they are engaged.

Apart from this, a set of tenders only in lump sums is unsatisfactory: first, because it gives no security against collusion; and secondly, because it gives no aid towards revision and adjustment, should it be found, as so often happens, that the amounts exceed the prescribed limits. It does not by any means follow that because a set of tenders differing not very widely are received for a work, that its proper value has been reached. The often hasty and irregular manner in which the quantities are calculated, as above described, may reasonably be expected to issue in mistakes, through which a man whose prices may be lowest, and facilities for executing work are the most advantageous, may be at the top of the list, and *vice versa*. Caucuses and combinations may be, and, if I am rightly informed, often are found amongst contractors by which they agree on whose bid is to be the lowest, the rest putting in at a small sum over it. Again, there may be items in the work which cost more than they are really worth to the design, and which, if the architect or owner knew the cost of separately, they would be glad to dispense with or modify. But supposing one of the tenders to be deemed satisfactory and be accepted: what means exist for the architect to adjust the amounts of the instalments to be paid on account? A mere lump sum for the whole gives him no guide in determining these. The same applies to the valuation and adjustment of such deviations, whether by way of addition or reduction, as may be ordered during the execution of the work. It is often provided that the amounts to be allowed for these are to be determined by the architect; but how? Without the possession of some better guide than the lump amount of the contract, all these matters must be mere guess work; and do we find in practice that either the public or the contractors are quite satisfied to abide by the guesses of the architect on these subjects? So far as my observation has gone, it appears to me that American architects generally do not command the confidence of either in this important part of their duty, and that consequently they are frequently displaced from the position they ought to occupy as sole umpires or arbiters between employers and contractors, and lose thereby both the emoluments and consideration which would attach to such a position.

The English system, in contrast with this, is as follows: During the preparation of or on the completion of the drawings and specification, the architect employs a building surveyor (one of a large, useful, and respectable profession), to "take out the quantities," as it is called, or in other words, to calculate with accuracy the amount of work of every kind required for the building. Should the architect be under any particular necessity for keeping within prescribed limits of expense, the surveyor often prices these himself, and advises the architect of the cost of any items that it may be desirable to modify or reduce, in preparing the specification. Ordinarily, however, this is not done till after the tenders are received. On the completion of the bills of quantities, they are lithographed, and a copy furnished to each party for whom a tender is to be received, whether they be invited by public or private advertisement. This, of course, relieves the contractors of nine-tenths of the trouble they have here, as, on receipt of the bills of quantities, they have only to append their prices and make up the amounts. As a consequence contractors can tender for ten buildings at less trouble to themselves than they can for one here, and the tenders are delivered with a promptitude and certainty that could not otherwise be attained. So fully is this system appreciated by the contractors as well as architects that it would be quite useless to ask for tenders in any of the great

cities without quantities being supplied. Contractors would very properly tell architects, if called upon to come and estimate from his plans, that they had better use for their time, and that of their clerks, than to calculate quantities for him or his clients merely on speculation. It is not by any means, as has been suggested to me here, that British contractors are not so intelligent as those here, and do not know how to calculate quantities. Builders or building contractors there are as shrewd and intelligent as are to be found anywhere, but just because of this they are unwilling, each one, to waste his time doing what one could do for all; and, if a surveyor were not appointed by the architect, they would either refuse to tender, or meet and elect one to do the business for them. Their experience has shown them what might be expected; namely, that a skilled surveyor who makes a specialty of the business is more likely to analyze the drawings correctly than any one else, and that bills of quantities prepared in this way are more full and correct than any they could prepare for themselves, even if they could spare the time necessary to be given to it. Just as a man who is his own lawyer has a fool for his client, they would consider a man who insisted on taking out his own quantities was a fool for his pains. I have no doubt but that respectable American contractors generally would think the same if but they were given the alternative, and up to the present my experience has fully sustained that view.

When the tenders are received, should the amounts be excessive, the maker of the lowest is ordinarily invited to confer with the architect, and produce, for the information of the latter only, his detailed estimate, based on the quantities, which shows, of course, the cost of each item, as well as of the whole work. It is reasonably assumed that both the architect and contractor should be interested in having the work go on to a successful issue, instead of being abandoned as might happen on account of its extravagance, and accordingly there is neither jealousy nor mystery between the architect and contractor, as seems to prevail here. Usually the possession of the detailed estimate enables the cost to be adjusted to meet the wishes of the owner; the alterations necessary in the specification are made, and the work proceeds. It is the usual condition in the contract that the contractor is to deposit with the architect a copy of the detailed estimate, and that it is to be the basis for ascertaining the amounts due as instalments during the progress of the work, also for valuing extras or omissions. It is not usually shown to the clients, but the possession of it is of great service to the architect as giving him an insight into the manner in which the funds at his disposal are being expended, and placing him in a position to do strict justice between client and contractor, which he would not otherwise occupy. The detailed estimate is of equal service to the contractor, as it enables him to order his materials and make sub-contracts with great facility, and it is just as much a protection to every honest interest of his as of the client.

The cost of taking out the quantities (or in other words the surveyor's fee) is ordinarily defrayed by a commission which varies in England from one to two and one-half per cent., and which in inviting the tenders is arranged to be paid by the contractor who gets the work, who of course duly provides for it at the foot of his estimate. Of course it really comes upon the owner, as is proper, for who else should pay the whole expense of a building operation? But all experience has shown that it is no extra expense, but, like an architect's commission or an insurance premium, is money laid out to advantage. No building owner of any intelligence would be found to object to it. Should the work be abandoned it has been held by the courts that it becomes payable directly by the owner. In no case is it chargeable to the architect, whose commission of five per cent. is even more distinct from this item than it is from the salary of the clerk of works.

Although retained by the architect for the purposes above mentioned, it is not usual in England to make the contract refer to the quantities, but to the drawings and specification. It follows, therefore, that should there be any error by which the contractor suffers loss, the surveyor is personally liable to him. This element, about which sometimes a great noise is made in the English journals, practically amounts to very little. Ex-

perience has shown that such mistakes are rare, and that in general surveyors do the business more accurately than could the contractors themselves, and no really qualified expert, whether he be surveyor, architect, engineer, lawyer, or physician, should be afraid to assume the fair measure of responsibility which the practice of his profession involves.

In Scotland, however, a difference exists, which is characteristic of that canny nation, and is really though not apparently more economical. The contracts are usually taken there with special reference to the quantities, the contractor agreeing to supply the amounts of work therein stated, but with this proviso, that should less or more be required for the execution of the building as shown in the drawings, the difference is to be credited or charged, as the case may require. This to some extent lessens the surveyor's responsibility, but often involves a remeasurement of the work; but it secures that the client only pays exactly for the amount of work he gets, and the builder is sure of being paid for all the work he has done. It is liable, however, to the objection that the contract amount is not so definite and fixed as under the English system, and however it may find favor in Scotland, has as yet not been adopted south of the Tweed. Of course the main principles involved are identical, one being that the architect should have a controlling power in regard to the estimates and cost as well as every other particular relating to a building, and that these should be calculated in a regular and systematic manner.

I think a fair consideration of this system, whether as practised in England or Scotland, will show that it is just as well adapted to the practice of this country as of the United Kingdom, and that the position and influence of the architectural profession would be largely improved by its adoption. I am confident that the want of such a system has a good deal to do with the public dissatisfaction with the profession alluded to above. It clearly rests with the architects to take the first step in its introduction, unless indeed they choose to resign their proper position as the masters of the art of building. My experience has shown that the American public and building contractors are by no means slow to discern the advantage of any improved system of business, and I have found both quite ready to admit and recognize the utility of this. Some contractors, I have heard, object, but on a principle which will scarcely bear examination. They say on that system any one can tender and the competition will be too sharp. This is practically an admission of the efficiency of the system, and can hardly be entertained by architects, who, being employed by the owners, should consult their interests first. But more than one contractor who has objected to the system has acknowledged that he did so because it would be a safeguard to the owner. I have found, however, that there are plenty of honest and responsible contractors ready to admit its great utility, and to avail themselves of it also whenever it has been fairly offered to them. From the great cost of building operations here in comparison with the United Kingdom, a much less rate per cent. would pay for the service here than what prevails there—say one-half to one per cent.—and would in all probability save ten times its amount besides the other advantages referred to as likely to result from its adoption.

The supposed unwillingness of contractors generally to conform to the system has been put forward by some architects to me as an objection to it. This unwillingness, as above mentioned, I have not found to exist, unless in a few cases, and with a class of men least deserving of the attention of architects. Even if it did exist, are the contractors to be looked on as the proper persons to decide such a question, or does it not rather belong to the province of the architects?

I believe there are plenty of contractors who would do without architects altogether if they could, and as a parallel to their willingness to make their own calculations, we find this class ready on all occasions to prepare plans also, as they profess, free of charge. If the architects be disposed to abdicate their functions in favor of such contractors in deciding one question, they might just as well do the same with reference to the other, and become mere draughtsmen, under the direction of the contractors, at once. If the architects are afraid to get proper calculations made in the interest of and for the protection of their clients, merely because certain contractors do not like it, they

might as well give up preparing accurate plans and specifications and the whole business of superintendence because the same class of contractors would much prefer doing without these things also.

Above all, the interests of the clients or building public imperatively demand that such an important branch of architectural business as the preparation of detailed estimates should not be neglected by the profession or handed over to those whose interests are adverse, and who, not being specially paid for them, can hardly be blamed if they keep their calculations for themselves, and try to recompense themselves in some other way.

The Scriptural question "Which of you intending to build a tower sitteth not down first and counteth the cost thereof?" must be answered negatively if we apply it to American architectural practice as it is; and if the result of beginning to build without being able to finish does not often take place, the almost equally unsatisfactory result of having to pay an enormous sum beyond what was originally contemplated happens too often, and, as in the case of the Governor's report already alluded to, brings no small discredit on the profession.

I trust that in instituting the foregoing comparison between British and American architectural practice, I have not overstepped the limits of fair criticism, my object being to place the experience of the profession in the old country at the service of those who practise the same in the new, and with a sincere desire and a sanguine hope that amidst all the progress making in other arts, the noble and important one of architecture may not remain behind, and that its professors may reap the benefit in being fully accorded the emoluments and consideration to which the practice of their art should so justly entitle them.

IRON AND THE SMITH.

From "The Builder."

GENERALLY the discovery of iron is understood to have been long posterior to that of bronze. While it is as yet impossible to affix exact chronological dates to the first introduction of any of the elder metals into the service of man, it is ascertained, beyond reasonable doubt, that the employment of gold was earlier than that of bronze, and that the manufacture of bronze preceded that of iron. Silver is interposed (perhaps in the first instance by the poets) between gold and bronze; but of the justice of that attribution it is difficult to form an opinion. It is, however, easy to understand that metal which is found in a virgin state, as in the case of gold, would more readily yield its resources to human industry, than metal found only in a state of ore. But even here we must speak with some reserve, as we are aware of the actual existence, although rare, of tolerably pure virgin iron, in the form of meteoric deposit, while we are unable to cite an instance of virgin bronze.

But while we cannot reduce the date of the earliest work of the smith to historic time, there is no reason to doubt the sequence of the various metals, in so far as they were known to or used by man. It is rather the philosophical than the historical or chronological date which we thus attain; but that is ample for our present need. At a distance of time which is uncertain, but which is to be measured by millenniums, rather than by centuries, and which may differ widely in different regions of the earth, the earliest inhabitants of our planet who have left any indications of their affinity to ourselves carved rude implements of stone, horn, and bone. Almost as early as any marks of industry of this nature are the relics of a contemporary art. Man began to ornament, so far as we can tell, as soon as he began to work. With the lapse of time, the rude flakes of flint, or the hammers made of some hard stone, assumed greater elegance of form and delicacy of finish. During the period which has been termed the neolithic age of civilization, bronze first made its appearance. Late in the bronze period, and, comparatively speaking, late in the historic period, we are accustomed to place the discovery of iron, to locate it in Crete, and to attribute it to the Idæan Dactyli.

Pliny, in his Natural History, says, "Of all metals the veins of iron are most abundant." The metal is mentioned, under its Greek name *sideron*, by Thucydides, Euripides, and Æschylus, as well as by Xenophon. The earliest note of the word occurs in the Book of Genesis (iv. 22) where Tubal Cain is mentioned as the instructor of every artificer in brass (or rather bronze) and iron. The word here used, which is also translated iron where it occurs in the Book of Ezekiel, is *barzal*, which is derived from an Aramaic root meaning to pierce. Another word, *paldah*, cognate forms of which also occur in Arabic and in Syriac, is used by the prophet Nahum (ii. 4), and is explained by Gesenius to mean steel. It comes from a root meaning to cut. The Hebrew *barzal* appears as *parzal* in the Book of Daniel. It is difficult to identify either of these words with the Greek form, although that is originally allied to both the Latin *ferrum* and the English *iron*. We are, however, relieved from any doubt as to whether iron was known in the time of Moses, 3,400 years ago, by the discovery of a wedge or plate of iron embedded in the masonry of the Great Pyramid itself.

This instructive relic, like the half-fuzed magnifying lens found at Pompeii, throws much light on questions of early workmanship. It has been a great puzzle to those who attributed the first use of iron to a date not much more than 2,900 years back, how such sharp and well-defined hieroglyphics could have been cut, by the ancient Egyptians, on porphyry, granite, and the hardest stone. It may, indeed, be the case that, when bronze was the ordinary material for tools, the coppersmith had some secret as to the production of a very hard temper, now lost. But this is at best only a guess. From the certain proof that iron had been produced and wrought in the age of King Cheops, 5,400 years ago, we can better understand how the innumerable and exquisitely sunk symbols and figures were wrought on tombs, temples, and sarcophagi. And more than that, from the great similarity in the mode of treatment, that prevailed from the time of the Ptolemies back to the very earliest known Egyptian inscriptions, we have something closely approaching a proof of the use of iron as far back as the fifth Egyptian dynasty, if not in the time of Menes himself; that is to say, six thousand three hundred years ago.

From that earliest use—date it when we may—the art of the founder and of the smith has advanced, with enormous strides, to our own times. If we distinguish the manufacture from the fabrication of iron—that is to say, if we draw a line between metallurgy and smith's work—there may be some reason for the opinion that, while the former is still in a state of rapid progress, the latter has passed its zenith. We are not about absolutely to insist on this point. Of the truth of the former position there can be no doubt. We must explain what leads us to entertain a suspicion as to the latter.

The great mechanical characteristic of the present age is the substitution of steam power for manual labor. The signal for this enormous change—a change which, it is not too much to say, is tending entirely to revolutionize the relations of mankind to the world on which they dwell—was given by the genius of Watt. Our own eyes have witnessed, our own hands have labored at, step after step, the mighty transformation. We can remember when, on one occasion, on the completion of a locomotive engine by Mr. Stephenson, steam was got up, and the machine, though well up to its duty on the rails, was unable to propel itself over the floor of the factory. The inference thence drawn, and not unnaturally, by the first engineers of the day was, that it was pure loss of time to turn attention to the propulsion of steam engines on the common roads. This was hardly a third of a century ago, and what do we now see? At almost every county bridge, in some districts, at least of England, a notice is affixed that the arch will not bear the weight of a traction engine. Who has not seen these uncouth giants tracking their heavy and resistless course over the country, training behind them wagons and quaintly-shaped machines for scarifying and torturing the face of the earth, with apparent indifference to their number or their weight. Two very simple improvements have overcome the impossibility imagined by Mr. Stephenson. One of these is the old mechanical method of reduction of speed by cog-work. The piston travels at the speed which best suits the evaporative power of the boiler. The driving-wheel revolves at the slow

pace fitted for progress over the road. This slow, irresistible progress is rendered possible by the great breadth of the wheels, and by the oblique grooving recently introduced on their circumference.

What has been done in the locomotive, from the express engines of Mr. Brunel, able to take a train over the low gradients of the Great Western Railway at the rate of seventy miles an hour, to the slow but mighty traction engines, and the self-moving agricultural engines of to-day, is going on in every department of the work of the smith and the fitter. Machines, not indeed endowed with intelligence, but unerring in their discharge of duty, and themselves the offspring of the noblest mechanical intelligence, now deal with iron almost as a swallow deals with mud. They forge, roll, hammer, plane, punch, and drill. They turn out hammered or pressed iron, untouched by the hammer of the smith, in every form; from the gun that weighs thirty-five tons to the hairspring of a watch. Hardly any tool can be named which is not produced, or likely to be produced, more readily, accurately, and cheaply, by machinery than by hand. But this great facility does not tend to improve the handiwork of the smith.

If we contrast this state of things with that which prevailed three hundred years ago, we shall see that against all our gain —and we are among the last to undervalue it—we have to set off a certain loss. The highest skill displayed in the work of the smith was found in the craft of the armorer. To that craft a fatal blow was given by the tilting-lance of De Montgomeri, when, in curious coincidence with the prophecy of Nostradamus, it entered the helmet of Henry II. of France. Three influences thus combined, and led, within a couple of generations, to the disuse of armor, and thus to the extinction of the most skilful, workmanlike, and artistic employment of the smith. These were the death of the King of France, which was too serious a matter to result without producing a powerful effect from the amusement of the tourney; the increasing excellence of gunpowder and guns, and the reign of a female Sovereign in England. When we look at the armor of the time; when we note that the tilting armor, which, by the introduction of the pauldron and other devices, had lost its symmetry, attained the weight of a hundred pounds avoirdupois; when we observe the exquisite delicacy with which the Milanese armorers wrought the mail that was like steel gossamer, or the scale or folding plate that fitted the limbs like the carapace of a lobster—we may well be of opinion that few smiths of the nineteenth century can hold a candle to their ancestors of the sixteenth.

Connected with the extreme care that was given to the fabrication of defensive amor, was that bestowed upon offensive weapons. The fame of two descriptions of sword-blades has been established since the Middle Ages, and even since the crusades. One of these is the Toledo rapier, a long, straight sword, the undoubted excellence of which must, we believe, be chiefly attributed to the original quality of the ore employed by the makers. The other was the Damascus sabre, or scimitar, a curved blade, of such exquisite temper that, when handled by a master of that description of fence, it could cut in two with equal ease a floating scarf of gauze or silk, or the neck of a horse, or of his rider. The excellence of the Damascus blades we are disposed to attribute rather to the skill and patience of the smith, or at least of the maker of the iron, than to the original quality of the metal. For it is to the repeated working up of scraps, and rusty scraps, of iron that the beautiful mottling of the Damascus blades is due. It seems to us not improbable that these numerous welds, none of which are so perfect as to have been obliterated under the hammer, act like the teeth of a very fine saw, and thus cut with a keenness unattainable by a more homogeneous and smoother edge. It should, however, be borne in mind that the difference between the iron produced from different ores is, in our present stage of metallurgic practice, extreme. There is an iron made in our North Midland counties which is so hard that it is almost impossible to break up old castings made of it. On the other hand, when the French *usines* began to make rails, some twenty-one years ago, an English fitter, with a cold-chisel and a hammer, could cut one of them in two in less than a quarter of an hour.

The earliest use of iron as an offensive weapon was probably in the form of ar-

row-head. Bright points of this nature, which are said to be a thousand years old, are preserved with great reverence in the museums of that wonderful country, Japan. It is far from improbable that meteoric iron was, in the first instance, thus employed. At all events, the purity of the metal, and the care and patience with which it was wrought, were extreme. Among the antiquities of India is to be found an iron column so large and so perfect that we could not produce the like at the present time without the aid of steam machinery.

After the demand for the highest class of smith's work—that is to say, armor and offensive weapons intended to pierce armor—had ceased, the decorative taste of Italy, of Germany, and even of our own country, was gratified by the production of much admirable ornamental iron work. Park and garden gates tasked the skill and displayed the taste of the smith. The uniformity of a line of iron palisades was agreeably broken by flourishes and scrolls, each of which was stamped by a certain individuality. In the South Kensington Museum are to be found fine specimens of English and Roman work of this nature. Much ironwork is now in rapid decay throughout the country, which it would be a good deed to rescue from destruction. We saw a beautiful specimen of this kind, not so very long ago, on a *perron* in the High street of Rochester. In other places the intelligent care of the proprietors, and the renewal of painting and of gilding, has kept the ironwork of the seventeenth century as fresh as that of to-day. Such are the goodly scrolls and flourishes that adorn the Town Hall of Guilford, and decorate its great projecting clock, erected in 1681.

To the demand for this bold, permanent, and manly kind of ornamentation a fatal blow was given by the increasing skill of the moulder and of the caster. The heavy railings recently removed from the west end of St. Paul's Churchyard were among the first, if not the very first, in which cast was substituted for wrought iron. It is said that the enterprising contractor made much money by his ingenuity in this respect. Economy soon prescribed laws of retrenchment as to ornamental ironwork; and here again, as in the case of the invention of gunpowder, the increased use of iron was made at the expense of the occupation of the smith.

The points to which attention are now chiefly directed, with regard to iron, apart from the mischievous result of ill-regulated competition in producing, for the smallest price, the largest possible quantity of inferior metal, are its reduction from the ore without the intervention of manual labor; the chemical purification of the metal, and the removal of those minute proportions of sulphur and of phosphorus which destroy its tenacity; and the production of steel or carbonized iron by simple procedures. There is, perhaps, no instance in which mechanical invention is removing a greater curse from labor than in the case of puddling iron. Those who have watched the process, or who have studied the beautiful representations of furnace-work given by the graceful pencil of Moritz Retsch, in his illustrations to Schiller's "Song of the Bell," are aware of the exhausting nature of the labor undergone by the puddler. It is, we think, the hardest labor now performed by man. As involving a certain amount of experienced judgment, it is of a higher grade than that of the brick-moulder; but the suffering it involves from heat is far keener than that inflicted, in the latter case, by cold and damp. For dirt they are about on a par. It is always the case that those occupations which, from their danger or their hardship, command extra wages, have a demoralizing effect on the workman. At the same time, just in proportion to the danger, especially if there be any risk of life, is it found that any attempt at introducing an easier process is steadily and fiercely opposed by those who think that they have acquired a vested interest in their craft. The manufacturers of iron are, to a great extent, at the mercy of the puddlers; and the chief gainers by the high wages which this arduous work rightfully earns are, no doubt, the brewers. It is, therefore, in the interests of morality, of public health, and of the elevation of the workman in the social scale, no less than in that of the manufacturer and of the purchaser of iron, a source of great satisfaction to find that the experiments recently made on the mechanical puddling of iron have been so satisfactory, that it seems now to be only a ques-

tion of time as to the entire disuse of the hand-puddling process.

Anything which tends to make manufactured iron at once cheaper and better is a boon to the smith. It is the bad quality of common iron, rather than any inherent defect in the metal, which renders the architect often averse to the employment of smith's work, when nothing else is so truly appropriate. We must conclude that what renders one sample of iron less tenacious than another is some chemical impurity in the metal, which it is within the power of perfectly instructed metallurgical skill to remove. These admixtures are often extremely small, if measured by any test but that of the depreciation of the quality of the iron. Measured by that test, their presence assumes extreme importance. Mr. Kircaldy, by his numerous experiments, has added no small amount of positive knowledge to that which we possessed before on the actual resistance of various makes of iron, both to tension and to compression. In his "Experiments on Wrought Iron and Steel," we find the breaking-weights of iron bars to range from 160,520 pounds per square inch of fractured area in the Swedish R. F. charcoal iron, to 63,883 pounds per square inch of fractured area in Russian C. C. H. D. iron, a difference not far short of three to one. In iron plates, looking at domestic production only, the breaking-weight per square inch of fractured area ranges from 92,468 pounds in Yorkshire plate to 43,460 in common Scotch ship-plate. This is more than two to one in favor of the Yorkshire iron. It is also a very suggestive comparison with reference to naval security.

An uncomfortable suspicion pervades the public mind—and even professional men are not altogether free from its influence—that, under some unexplained circumstances, the texture, or molecular arrangement of iron used in buildings or in machinery, undergoes a mysterious change. Fractures of axles or of tyres in railway collisions are the phenomena which have been chiefly cited as requiring this very alarming explanation. Many writers have ridiculed the idea; but ridicule is an unsatisfactory substitute for scientific analysis. It has, however, been pointed out that "the two different appearances, respectively known by the terms 'a fibrous fracture' and a 'crystalline fracture,' are produced by the iron breaking gradually in the one case, and suddenly in the other. Hence, when the appearance presented was fibrous, it only proved that the piece had been torn asunder; when it was crystalline, that it had snapped." This view, which is not a matter of theory, but the outcome of experiment, fully explains all the phenomena of fracture which have led to the idea of some unexplained structural change. It is of the first importance, to the architect as well as to the engineer, that the facts should be known. An unexplained, mysterious danger, such as would be that of such a molecular change, if it could possibly occur without ascertainable cause, is more to be dreaded than any of those casualties which it is within the power of competent science, backed by competent care, almost absolutely to preclude.

By immersing specimens of iron in dilute hydrochloric or muriatic acid, the foreign impurities are removed, and the texture of the metallic portion is exposed to examination. Long immersion in water—or at least in *some* water—has the same effect, as we have witnessed in the bolts of a sunken vessel that had been for some fifty years exposed to the alternate action of fresh and salt water in the river Seine. Thus treated, puddled iron, rolled or wrought iron in its lowest state, as in Scotch and Welsh puddled bars, presents a woolly appearance. In iron of a superior quality the appearance presented is that of very fine threads or hairs, lying closely together. This is remarkable in Farnley or Bowling iron, as also in Russian bar. Swedish tilted bars present, even to the naked eye, a beautiful silvery variegated appearance. Of the beautiful Styrian iron, which is so highly prized in Italy, and which was probably employed by the famous armorers of Milan, we regret that we have found no analysis or definite scientific description. It is most evident—to use a mode of expression that has recently come into favor—that there is iron and iron, no less than that there are smiths, and that there have been smiths.

LONG RAILWAY RUNS.

From "The Engineer."

It is a well understood proposition, and one generally accepted as true, that nothing operates more effectually to increase the time spent in accomplishing a given journey by rail than working trains on the short-run system; and it is also true that so-called fast trains which stop frequently are the most expensive that it is possible to use. The reason for this last fact is obvious. Not only is much fuel wasted in doing work which is afterwards undone by the brakes in a way which we have already fully explained when dealing with the rolling stock of the Metropolitan Railway, but the speed of the train when running must of necessity be very high in order that the train may, in any sense, fulfil the condition of being "fast." But high speeds represent a great consumption of fuel, and augmented wear and tear of engines, carriages, and road; and it will be found, as a result, that very few fast stopping trains are run by railway companies who understand in what true economy consists. Trains which stop at many stations in close proximity are essentially slow, no attempt being made to travel at a high velocity between the stations; and those who require conveyance over long distances select trains the average velocity of which, measured by the mile, is not very high—continuous running without a break getting the train over the ground in excellent time. As an example of the latter class of train we may take the Scotch mail on the Great Northern. This train accomplishes the whole distance between London and Edinburgh—about 400 miles—in nine hours and thirty minutes, the average speed being about forty-two miles an hour. It would be necessary to run this train at an enormously higher velocity if the stops were more numerous. As it is, we believe we are correct in stating that on no other line in the kingdom is a train to be found which gets over a greater distance in nine and a-half hours. It is true that on the Great Western trains are run which accomplish 200 miles in about four hours and twenty minutes; but a run of 400 miles is not made on any line, save the Great Northern, in much less than ten hours. Long runs require very good engines and excellent rolling stock; but these being given, long runs are decidedly conducive to economy, and there is no reason why they should not be more freely adopted than is now the case on many important lines, and on all such lines the principle apparently might be extended with advantage. For example, there is apparently no good reason why the run from London to Liverpool, *via* Runcorn, should not be accomplished without a stop, or at all events with but one stop, and in say four hours, the distance being, as nearly as may be, 200 miles. The road could not easily be made much better than it is, but the existing carriages would, for obvious reasons connected with the comfort of the public, not be suitable for such runs, and something in the nature of Pullman cars would be essential; at all events, free circulation through the train would be required. But this presents no difficulty. It is perhaps open to doubt whether a locomotive could be constructed which might be relied on to accomplish a journey of 200 miles in four hours without stopping, and the work would no doubt be exhausting to both driver and stoker. We have already expressed our opinion concerning the locomotives required for such work in a former impression, and we shall not further refer to the matter now, except to say that we believe it to be quite possible to construct engines which would be perfectly reliable, although they would, in some important matters of detail, differ from ordinary locomotives. The great difficulty to be contended with in working trains on such a long run as that under consideration lies in providing water enough. This would not stand in the way of the London and North-Western Company, who may use Ramsbottom's tanks, of which they have at present the monopoly. But it would be otherwise with the remaining English companies, who, precluded from using Ramsbottom's system, would be compelled to resort either to the use

of tenders of unprecedented dimensions, or to some other device for filling up their tanks. There are grave objections to the use of large tenders, which would probably neutralize all the advantage to be gained from long continuous runs, but it is by no means certain that Ramsbottom's is the only arrangement by which a tender while in rapid motion can be replenished with water.

The idea of working trains between London and Liverpool direct resulted in nothing, although at one time it was stated, with some show of authority, that the directors were actually providing the requisite rolling stock, and on the Midland Railway trains no longer run without a stop to Leicester—a fact in some measure accounted for by the difficulty met with in providing water without the aid of the Ramsbottom trough. It may, from these circumstances, be argued that the long-run system is already fully developed; but this we dispute. We have very little doubt that, on the contrary, as great towns such as Liverpool increase in size, it will become almost essential to establish a railway service between them and the metropolis so rapid and so heavy that it can only be dealt with by trains running directly from city to city without a stop. If, for example, Liverpool can provide a sufficient number of passengers to London at any given hour in the twenty-four to fairly fill a train of say twelve coaches, it will be worth while to run that train through to London without a stop; and we feel certain that, if such a through train, properly constructed, were put on to-morrow, making the run say in four and a-half hours, it would not only be the most popular train on the road, but also the train worked most economically. However opinions may differ in this country as to the value of the long-run system, it is certain that our friends in the United States are determined to give the system a fair trial. Since the 1st of June the Pennsylvania Railroad Company have commenced working long-run trains between Pittsburgh, Philadelphia, and New York. The distance is 444 miles, and the train stops on the road but three times: at Altoona for five minutes, after a continuous run of 117 miles from Pittsburgh; then comes a run of 132 miles to Harrisburg, where the train stops for twenty minutes for dinner; the next stage is to Philadelphia, 105 miles. The train stops here for five minutes, and then proceeds across New Jersey for 90 miles to New York. Nothing at all comparable to this work has ever before been done on a railway except once or twice by special trains under exceptional circumstances. The run of 132 miles is no doubt a wonderful feat, and redounds not a little to the credit of American engineers. The entire line, we may state, is laid with 60-lb. steel rails, laid on oak sleepers and thoroughly well fished, the track being admirably ballasted. The train is made up of Pullman cars of the most luxurious description, and fitted throughout with the Westinghouse brake; the engines are supplied with water when running on Ramsbottom's system, and no pains appear to have been spared by the company to provide for the safety and comfort of the public.

As regards the velocity of this train, we learn from the published time-table that the train leaves Pittsburgh at 7.25 A.M. and reaches New York at 9.30 P.M. Deducting half an hour for stopping, we have as the total running time 14 hours 5 minutes, or say an average velocity of 31.7 miles an hour. Not a high speed certainly, but in no other part of the world is it easy, we believe, to accomplish a distance so great in the given number of hours. The first run of 117 miles is performed in four hours, or at the rate of 29.25 miles an hour; the next run of 132 miles is done in four hours, or at the rate of 33 miles an hour; the distance from Harrisburg to Philadelphia, 105 miles, is run in three hours fifteen minutes, or at the rate of say 32.3 miles per hour; the final 90 miles across New Jersey being accomplished in two hours and fifty minutes, or about 32.1 miles an hour. We take it for granted that no great difficulty would be encountered in running the train at a higher speed, and performing the whole distance say in ten hours instead of fourteen if it were worth while. As the facts stand, however, they prove that in America work is being done which deserves to be imitated in the old country, and its importance in a new and thinly populated country like the United States cannot easily be overestimated. We have no doubt that the possibility of running a locomotive con-

tinually and regularly for a distance of 132 miles will only give an additional stimulus to our American friends; and so, if we do not mind what we are about, we shall have some enterprising Yankee coming among us and bringing with him his own engines and cars, and running regularly from London to Liverpool in four hours, while we are debating whether it is possible to design an engine which can run for four hours without stopping and without a breakdown. Not the least remarkable feature in the working of the train to which we have referred is the circumstance that the engines make continuous runs of four hours without heating or getting the tubes so choked up that they cannot keep steam. We commend the facts to the attention of our railway men.

NOTES ON THE SUBSTITUTION OF STEEL RAILS FOR THOSE OF IRON IN THE CONSTRUCTION OF RAILWAYS.

BY M. DESPRET

(*Read before the Brussels section of the Association of Engineers.*)

From "The Review of Mining."

The writer of this paper proposes to answer the two following questions:

First.—*Under what circumstances is it advantageous to make use of steel rails instead of those of iron?*

Second.—*In what manner should steel rails be employed?*

In order to answer the first question, M. Despret is of opinion that several matters should be taken into account.

In the first place, the causes which influence the durability of iron rails.

Next, the cost of periodically relaying the rails.

Next, security in the passage of the trains.

And lastly, the modifications which may eventually be introduced into the form of rail now in use.

M. Despret commences by passing under review the causes which influence the durability of rails. These causes may be classed under two heads: those which are inherent in the rail itself, and depend on its quality and the material it is composed of; and those which, although unconnected with the rail itself, depend on the action of the wheel-tyres upon the rail.

As regards their material, rails may be made of either iron or steel, but the latter offer a much greater resistance than those of iron to the strain caused by the passing of the trains. This superiority consists not only in their chemical, but also in their physical composition—steel rails being perfectly homogeneous, while those of iron are composed of different layers imperfectly welded together.

With respect to their quality, steel rails give greater guarantee of stability than those of iron; the quality of the latter being excessively variable, while that of the former is much more uniform.

The steel rail should, then, endure far longer than the iron rail. Opinions are, however, much divided as to the relative durability of the two, some engineers maintaining that the steel rails will last only twice as long as those of iron, while others assert that ten times is the correct proportion.

M. Despret brings to this subject the result of experiments which he has made on a portion of permanent way with a gradient of 18 to 20 millimetres per metre (1 in 50 to 1 in 55.) Iron rails of excellent quality, laid on this gradient, have lasted three years, with a wear of 10 millimetres (0.393 inch); while steel rails, which were laid on the same gradient four years ago, have undergone, after these four years of service, a wear of only 4 mil. (0.1572 inch), the table preserving, at the same time, a perfectly regular form. If these steel rails continue to wear in only the same proportion, they will last three times as long as those of iron.

M. Despret remarks, that in comparing the relative durability of steel and iron rails, account should be taken of any improvements which may be introduced into the manufacture of iron rails. Among

these improvements, he especially mentions that which would result from the use of the Danks furnace for puddling, thus allowing of the manufacture of iron rails, the homogeneity of which would approach that of steel rails.

Passing on to the action of the tyres on the rails, M. Despret remarks that this action is more or less intense, and that its intensity depends—

Upon the traffic;
Upon the load on the wheels;
Upon the speed of the trains;
Upon the section of the line;
Upon the laying of the permanent way;
And lastly, upon the state of maintenance of the tyres.

M. Despret analyzes the action on the durability of the rails of each one of these causes, dwelling especially on those which exert the greatest influence on this durability.

The wear of rails is in proportion to the traffic—that is to say, to the number of trains passing over the line. It would be very interesting to know how many trains could pass over a rail before it became unfit for service, while taking into account any other circumstance, independent of the traffic, which might influence the durability of this rail. Experiments made by the Lyons Railway Company have furnished these data, in the case of iron rails laid down where exterior causes of deterioration can only exercise a secondary influence. The result of these experiments is, that an iron rail of good quality, laid under these conditions, can endure, before being rendered unfit for use, the passing of 5,000 trains; that is to say, for a traffic of 8,500 trains per annum, on a line of way—which corresponds very nearly to 23 trains a day—the rails of this way, if rolled of iron of good quality, should last 10 years.

The load on the wheels exerts a more or less destructive action on the rails, in direct proportion to the amount of this load.

M. Despret, remarking that under ordinary conditions, a mean load of 12 to 13 tons per axle was usually admitted, gave it as his opinion, that on account of the insufficient stabiliiy of the permanent way, it is advisable not to increase this load on a single pair of wheels, and especially not to reduce the wheel base.

The section of the line has great influence on the durability of the rails. When the gradients are sufficiently steep for the force of gravitation to exceed the inertia of the trains, it becomes necessary, in order to moderate their speed in descending gradients, to bring the brakes to bear, which cause considerable deterioration to the rails.

The rails laid on curves also suffer damage to a greater extent than those laid on straight portions, and their deterioration from this cause is greater as the radius of the curves is less.

On certain portions of the line, independently of all other equal conditions of wear, the rails are subjected to exceptional strain; these portions are near stations, at stations themselves, where frequent shunting takes place—in fact, wherever it is necessary to apply the brakes frequently.

After thus analyzing the causes which influence the durability of rails, M. Despret points out the effect which they produce. Those causes which are not inherent in the rail itself produce more important deteriorations in proportion as a greater number of them act at the same time, and also as the action of each of them is more intense. Though these causes seldom act all together, they never act singly, and the effect which they produce upon the rails will be greater or less according to the degree of intensity of the causes which operate at the same time. On the other hand, these effects will be different according as the rails are of iron or steel, and also in proportion to their quality.

The second subject to be considered, in order to solve the first question, is the expense resulting from the periodical renewing of the rails.

This expense is represented by the difference in value between the new and the worn-out rails in addition to the labor required for relaying. In order to compare the expense due to the periodical renewing of the iron rails with that of the steel rails, the durability of each, and also the interest on capital expended in their purchase, must be taken into account. A table might therefore be prepared, showing the expense per annum incurred by the renewal of the line with iron as against steel rails, corresponding to the different periods of the duration of each.

It appears from a table prepared with this object, that, in order to preserve the same annual expense, the steel rails should last at least twice as long as those of iron.

A third subject which should be taken into account is security to the traffic. In connection with this point, M. Despret remarks, that in certain portions of the line, accidents which are due to the rails are always of a serious character, as for instance, in tunnels, on high embankments, and on viaducts. In these portions of the line nothing should be neglected to ensure the stability of the permanent way, including the use of rails which afford the greatest safeguard.

Lastly, account should be taken of the modifications which may be eventually introduced into the form of rail at present in use.

With reference to this subject, M. Despret calls to mind the numerous experiments that are made to improve the permanent way. Among the systems tried, there are some in which the present form of the rail is completely altered. Even if the present section be retained, the question may reasonably be asked, whether it will not ultimately become necessary to increase the area of the section, in order to present a greater resistance to the load that may be brought to bear upon it.

In prospect, therefore, of future modifications, the present section of the rail must not be calculated for a too long duration. In fact, inasmuch as the use of steel rails only becomes economical under the condition that they last at least twice as long as those of iron, it might happen that the steel rails would have to be taken up before they had rendered all the service that might be expected of them to make their use economical.

What period, then, would it be advisable to set to their duration? M. Despret is of opinion that it should not exceed twenty years.

After having passed in review the different matters which it is necessary to take into account in order to answer his first question, M. Despret gives the answer in the following terms:

In the first place, steel rails should be universally employed where the safety of the train is at stake; as in tunnels, on viaducts, or on high embankments. Steel rails should also be employed on all portions of the line where iron rails can only be expected to last ten years, that is to say—

In all lines where there is a greater traffic than 8,500 trains per annum.

In all gradients greater than 10 millimetres per metre (1 in 100), descending in the direction the trains run.

In curves the radius of which is less than 500 metres (nearly 25 chains).

In the proximity of stations, where the speed of trains must be slackened.

In stations, and in those portions of the way where shunting takes place, or where the brakes are frequently applied.

In order to enable the import of these conclusions to be realized more readily, M. Despret applies them to the Luxembourg line.

When this railway had only a single line of way, there was reason to make use of steel rails over its whole extent, because more than 8,500 trains passed yearly over this single line of way.

When the way was made double, however, the conditions as to the use of steel rails were altered. As the number of trains on each pair of rails became only half what it was before, the traffic was not such as would justify the employment of steel rails; but other circumstances, under which their use was warranted, might be taken into consideration, and especially the inclination of the gradients. Thus, in the portion of the line traversed by trains going from Brussels to Arlon, steel rails should be laid on all gradients steeper than 10 millimetres per metre (1 in 100), descending towards Arlon, and, inversely, on all portions of the up line of the same descending gradient traversed by the trains going from Arlon towards Brussels.

M. Despret next takes into consideration his second question, which is in the following terms:

How should steel rails be employed?

Up to the present time, the managers of railways who have made use of steel rails, have confined themselves to the change of substance and not of form of their rails.

A French company, that of the Northern Railway, have looked at the matter in a different light. Starting from this fact, that steel rails are much stronger than those of iron, this company has

adopted a steel rail instead of one of iron, but has reduced the section from 37 kil. (81½ lbs.) to 30 kil. (66 lbs.) per lineal metre (1.093 yard).

M. Despret read several passages from a report published by the Northern Company, in support of the system which it has adopted. After enumerating the advantages possessed by steel rails over those of iron, the report says:

"The advantage of the substitution of steel rails for those of iron is then evident, if the first cost be not considered an objection; now, in actual practice, by taking advantage of the difference in the strength of the two materials, the rails may be reduced to 30 kil. per lineal metre, still leaving them of superior strength to the iron rails which they replace. By these means, not only will the excess of first cost be reduced, but also the cost of laying will be much more economical than those of iron rails."

M. Despret differs with the report as regards the saving consequent on the adoption of the steel rail of 30 kil., inasmuch as the result at which the Northern Company has arrived is founded on a difference of only 70 fr. (£2 16s.) per ton for the steel rails, whereas the difference, at least in Belgium, is much greater.

However that may be, by applying the prices current in Belgium to the laying of a line with steel rails of 30 kil., as against iron rails of 37 kil., M. Despret finds the cost of the way with the former rails is not much greater than the construction with iron rails of 37 kil.

In the adoption of steel rails, then, there is a choice between two modes of action; in the one the section of the old iron rail is preserved in the new steel rail, and in the other this section is reduced.

To the question, Which of these two systems should be followed? M. Despret declares himself at a loss to give a decided answer.

If the iron rail of 37 kil, in general use at the present day, was found to be of insufficient strength, there would be no hesitation in taking advantage of the increased strength of the steel, by giving to the rails manufactured from this metal the same section as the iron rails of 37 kil.

Now, the question is, whether this iron rail of 37 kil. is of insufficient strength or not.

With regard to this subject, M. Despret recalls a very interesting discussion which took place in 1864, at a meeting of the Societe des Ingenieurs Civils de France, on the occasion of the publication of a treatise by M. Eugene Flachat, on the wear and the relaying of rails.

In this treatise, M. Flachat maintained that the iron rails of 37 kil. were found to be of insufficient strength, and that it had become necessary to increase their section. All the engineers of the great French companies took part in the discussion, and they all declared that, in their opinion, the iron rail of 37 kil. was sufficiently strong, provided that it was of good quality.

But M. Despret remarks that the conditions of the traffic are not the same as they were ten years ago. Heavy engines, with a large number of axles and short wheel base, which cause considerable strain to the permanent way, were in 1864 only the exception; now their use is becoming day by day more extended, and it may even be reasonably asked whether the power of these engines will not be still further increased, so as to increase at the same time the load on the wheels.

Under these circumstances, there is great reason to fear that the iron rail of 37 kil. will not be sufficiently strong, and therefore there may well be hesitation in adopting a reduced section for the steel rail.

Notwithstanding this, M. Despret considers that the Northern Company have reason for the decision arrived at by them. On a system like that of this company, there is not the same strain on all portions of the line; and by adopting the steel rail of 30 kil., the Northern Company can immediately work up again the steel rails on those portions of their way liable to the greatest strains, without incurring any very great loss. If, in future, these rails of 30 kil. should be found of insufficient strength, they can be replaced by those of greater section, and still utilized on the portions of the line where the traffic is lighter.

M. Despret remarks, in conclusion, that the results of his investigation lead him to consider, that although the question of the substitution of steel rails for those of iron may now be settled in principle, it is far from being settled in all its details, and that because a sufficient amount of experience, which requires a lapse of time, has not yet been acquired to determine precisely all the conditions respecting the employment of steel rails.

FRENCH ENGINEERING IN THE EAST.

From "The Building News."

NEARLY thirty years ago a number of French engineers persuaded the ruling prince of Egypt that he might bestow inestimable benefits upon the country, besides creating for himself an imperishable renown, by undertaking to construct a barrage, or dyke of prodigious dimensions, in combination with a system of canals, which should reclaim from sand and salt marsh the richest of the Egyptian lands that had lain uncultivated for centuries. The history of this project, now that it has been illustrated by the recent inundations, and now that, according to the last authentic intelligence, it has come to a close, through the works having proved useless in a double sense, is worth remembering. They were intended to provide water where there was none, and to regulate its overflow when there was too much; and they accomplished neither purpose. The able but imperious Pasha Mohammed Ali, infatuated by some professional men from Paris, conceived the idea of superseding all natural and traditional provisions or artifices for the irrigation of the soil by erecting a stupendous dam, connected with a labyrinth of channels, which should at once restrain and distribute the annual flood. To this end he almost stopped the navigation, paraded his plans on Parisian maps, set an array of half-starved peasants to labor upon mounds of earth and aqueducts of masonry, and expended upon engines and engineers, both French, an incalculable amount of money. The promoters took a pride in attributing so grand a scheme to the First Napoleon; but a quarter of a century after the barrage of Mohammed Ali was begun, it was in the same condition as another, constructed six hundred years before, which the Nile, at its first extraordinary rise, overthrew. It is well known that the Nile, approaching the sea, divides into two branches—the Damietta and the Rosetta. It was here that the projectors thought to store up the waters which had come down from the upper regions, by throwing dams across both channels; yet, after an incredible waste of toil and treasure, their work remains a ruin, never to be repaired. No doubt its originators had an amount of reason in their hope, which was, however, too daring for fulfilment through any means at their command, though a generation which has witnessed the completion of the Mont Cenis tunnel and the Suez canal might possibly not shrink from reviving this ambitious scheme were it founded on a more practical basis. For, as it has been plainly described by the French engineers, the object was to hold up the waters of the Nile, during the eight months of ebb, so as to maintain them at the level of the soil and supply Lower Egypt during that period with the same amount of water as the period of the yearly inundation, it being estimated that the enormous expense of the work itself and the new system of canalization it would necessitate would be more than compensated for by a vast increase of cultivable land in the Delta, or space between the two arms of the Nile, and the setting free of innumerable hands from raising water for purposes of tillage. The conception was worthy, perhaps, of old Egypt; unhappily, the attempt at its execution, since the first stone was laid by Mohammed Ali in 1847, has been incommensurate. The foundations of a double bridge were raised, spanning the ample stream, with its deep, soft, muddy, and changeable bed—an experiment such as that of damming the Thames at Greenwich, with a full tide running and no bottom to hold by. The engineers got on famously at first; they threw up a series of light and lofty arches; they created an imposing architectural facade, turreted with admirable effect above each of the sluice-gates, and towered in the centre and at the corners. Nothing could be more majestic than the general aspect of the barrage as it promised to approach completion, and nothing more apparently practical than the apparatus of sluices, with their double cones of hollow iron, working, as Dr. Russell says, on radii of rods fixed to a central axis on each side of the gate. These cones increased in dimensions from the bottom to the top, the lower filling with water as they descend-

ed into their beds of masonry. It was never proposed to keep them shut all at one time, because the pressure of the Nile, rolling from its remote fountains, would in that case have probably swept the entire elaboration away; but even then it was found that these ramparts raised against nature vainly struggled with it. The locks, with their terraced quays, speedily exhibited signs of dislodgment from their sites; the archways burst; the canal-ways were gorged; the neighboring dams of earth availed nothing; and what is left of the barrage at this day attests a colossal scientific failure, the results, such as they continue to be, proving mischievous rather than beneficent to the country, not one shilling having been returned to the Viceregal treasury of the millions upon millions sterling that were sunk. It was so formerly in India, where a French engineer was not less essential at every native court than a French colonel of cavalry. This is said without disparaging in the slightest degree the science of France; it points rather to the pseudo-science of adventurers, half political and half financial—for nothing could be more absurd than any depreciation of foreign engineers in these respects. A peculiar genius, however, belongs to every nation, consequent, in a great measure upon the necessities which create habits. Thus neither the English nor the French have any monuments to display equal, or even similar, to the sea-dykes of West Cappel, the Helder, and the Isle of Walcheren, in Holland; they do not require them, though the requirements of coast-railways are often formidable enough. And yet the great dam of the river Fureus, St. Etienne, France, is a trophy of enterprise and skill, though not upon any gigantic scale; it secures an immense body of water in permanent reservoirs; it guards against all danger of overflow; it has needed scarcely any reparation during the last twelve years; and it has withstood the shock of a waterspout historically calamitous. There is a barrage too, in Spain, fifty yards high, and two hundred years old, but curvilinear in form, whereas all the French barrages are straight; but both differ in many essential particulars from the Egyptian, in which more masonry is employed, more sluices are capable of being opened, and an artificial foundation was sought, though never found. The engineers at Fureus had a rock to build upon; those of the Nilotic Delta never found their way, properly speaking, through the quicksands or the mud. Little wonder, then, that the last vestiges of their labors are vanishing. Mr. Aymard, in his book on Irrigation in Spain, gives a history of the barrage at Puentes, which cost an astonishing sum, and which gave way at the base in 1802, the architect having conceived the notion of founding it upon piles in an alluvial soil, instead of going down to the solid rock at any sacrifice. Remarks of a similar kind have been applied by the highest authorities to most of the dykes of this complex kind, composed of bridge, dam, and tunnel at once, in Europe, and they apply with tenfold force to the magnificent "Folly" of Mohammed Ali and his Parisian engineers in Egypt. As a last resource, the reigning Viceroy and his predecessor thought it practicable to recover from the ruins of the French barrage some aids towards the construction of a new one by English engineers; but the advice given them, and to the former, especially since the late disastrous inundations, has been to get rid of the obstruction altogether. Nothing less than the dimensions and solidity of a breakwater would curb, in redundant seasons, the fall and flow of the Nile, carrying with it, as it does, the impetus of thousands of miles, gathered from elevated sources, and only moderately diminished in its progress through the lakes and down the endless valley.

Even in constructing the Suez Canal, the French engineers discovered many difficulties and perils upon which they had not originally calculated, and peculiarly so in the case of the necessary embankments; but what was the scientifically-arranged meeting of two seas in comparison with the perpetual downpour of a river so fluctuating, and yet so voluminous and incessant as the Nile? It was not as a protection against the waves and winds of the Mediterranean alone that the Cyclopian breakwater of Alexandria was designed, but also against the turmoil of the waters caused by the irregular rushing of the great Egyptian stream. As an illustration of the meaning implied, reference may be made to some vast works

undertaken, not long ago, on the Danube. In the recommendatory report, it was suggested that the current should be, in some measure, controlled; but the ultimate decision was to smooth the bed, to set the water free by all possible expedients, to deepen and straighten instead of curbing or diverting; and this is the lesson which, after the life of a generation, has been learned in Egypt. The barrage of the Nile, with all its complications of dykes, viaducts, sluice gates, tunnels, canals, and pumps, was far from being pronounced complete when it became a ruin, and a ruin it will remain until the last traces of M. Linant's ill-judged undertaking have been either swept away by other floods or overwhelmed by the sands. It is, and was from the commencement, to be feared that the work was urged upon the successive rulers of Egypt from political motives rather than from any real belief in its feasibility; but the reminiscence is an unpleasant one of the extorted toil, no less than of the extorted taxes, wrung from a poor and helpless population to aid in this realization of a dream indulged in by a Franco-Egyptian Society which once actually proposed the drainage of the Lake Mœris, as though Egypt were Holland, unduly invaded by the billows. Of course a philanthropic incentive may have prompted some among the engineers who pressed their services upon the Pasha Mohammed Ali and his equally credulous successors. It would have been a great advantage, no doubt, if the immense amount of manual labor now devoted to raising driblets of water from the river by rude appliances of primeval fashion, which have exhibited no improvement for centuries past, could have been saved, and this, indeed, was among the objects proposed to be fulfilled by M. Linant's unfortunate barrage: but the same end could have been obtained, at a hundredth of the cost, by another process, as was demonstrated at the very time when these leviathan plans were being drawn, by an Egyptian prince of a different mould (Ibrahim Pasha), who established stationary steam engines on his estates, which increased in fertility and value while the dykes, and the arches, and the canals, were in progress, with a view ultimately to foster harvests on the waste lands of the valleys, though in reality to bequeath fresh evidence—as if any were needed—of the truth that an idea may be theoretically grand and practically worthless. These Pharaonic works neither interested nor enlightened the poor peasants in whose behalf they were said to be undertaken. They simply served the purpose of a few speculators, and their destiny has culminated in a general swamping and downfall. Henceforth the latest trophies of the modern Pharaohs will present to the traveller's eye a few groups of unpicturesque fragments, scarcely coherent enough to tell the tale of their original design.

LOSS OF PRESSURE IN STEAM PIPES.

From "The Engineer."

It is well known that the initial pressure in a cylinder seldom equals the boiler pressure; certain exceptions to this rule exist, however, to which we shall refer presently. The loss of pressure is usually attributed to the frictional resistance of the steam pipe and condensation within the latter. There is reason to believe, however, that although such a deduction is consistent with facts in many cases, it is by no means always so. In other words, the proposition that friction and condensation in a steam pipe are the cause of a difference of pressure between the cylinder and the boiler is not invariably true under all circumstances and conditions. Indeed, there is reason to believe that in all cases when the steam pipe is of sufficient diameter the loss of pressure due to any influence which it can exert must be trifling. The question is one of growing importance, especially in our mining districts, because it is becoming more and more the practice to transmit steam from a boiler to an engine through very long distances. Pumping engines of great power are now fixed at the bottom instead of at the top of a shaft; and it is found to be more economical to take steam down the pit than to adopt

heavy spears and plunger holes. If, however, it could be shown that any great loss of power and fuel must follow on the adoption of this system of construction, it might be better, after all, to resort to the old style of practice familiar to all engineers. It is somewhat remarkable that very few experiments have been made to determine what is really the effect of a long steam pipe on the power of an engine and the consumption of steam; and in the absence of experimental data, we must reason a good deal on theory in dealing with the question. Enough is known, however, to enable us to arrive at tolerably accurate conclusions as regards any given case.

In practice it is found that the difference between the pressure in the boiler and in the cylinder of stationary and marine engines is about 3 lbs. We have ourselves verified this fact dozens of times. The difference is sometimes a little more, sometimes a little less, but this may be taken as a fair average; and, curiously enough, it appears that the difference is very nearly independent of the boiler pressure. Thus, in an old-fashioned beam engine working with a boiler pressure of but 10 lbs., and having a piston speed of about 240 ft. per minute, the maximum indicated cylinder pressure was but a shade over 7 lbs. The steam pipe was short—about 15 ft. long—large and well clothed. In another case, with a boiler pressure of 70 lbs. and a steam pipe about 20 ft. long imperfectly protected, the initial pressure in the cylinder nearly reached 67 lbs. In a third instance, with about 20 ft. of well-felted 8-in. pipe, the initial pressure in the cylinder of an engine, 27 in. diameter, 3 ft. 6 in. stroke, running at 60 revolutions per minute, was 50 lbs., the boiler pressure being a little under 54 lbs. We could add many other cases to prove the accuracy of our proposition if they were required. Why it is that the difference is apparently independent of the pressure we are unable to explain in any way quite satisfactory to ourselves, so we must rest content with stating the fact. If any engineer will take the trouble to fit a steam pressure gauge on a valve chest, he will learn in two minutes that the received ideas of loss of pressure in steam pipes are erroneous—that is to say, if the pipe is of sufficient diameter. He will find that the hand of the gauge is in constant motion, falling with each opening of the steam port, and rising again when the valve closes. In single-cylinder engines, especially when working expansively, there is an intermittent flow of steam through the steam pipe. The moment the valve opens the steam in the valve chest rushes in, and the whole body of steam in the pipe has to be suddenly put in motion. Its inertia must be overcome, but before this can be done a considerable fall in pressure must take place in the valve chest and that part of the column next the engine; and it is not difficult to calculate exactly what this fall in pressure must be if we know the weight of steam in the steam pipe, and the required velocity. But at the moment the valve closes, the steam is in rapid motion. This motion is suddenly arrested, and the pressure in the valve chest may then, by the impact or momentum of the column of steam, rise considerably above that in the boiler for an instant. Mr. D. K. Clark cites cases in which the pressure in the valve chest was as much as 8 lbs. higher than that in the boiler from this cause. The difference between the initial pressure in the cylinder and that in the boiler appears to be in all cases almost wholly due to the resistance of the steam ports, and the inertia of the column of steam in the pipe, and little, if at all, to the resistance of the pipe or to condensation. Mr. D. K. Clark has found that the resistance of the steam pipe is quite inappreciable even in locomotives running at 600 ft. of piston per minute, when the sectional area of the steam pipe was not less than one-tenth of that of the piston; and Rankine states that, provided the velocity of the steam in a supply pipe is not suffered to exceed 100 ft. per second, the frictional resistance of the pipe may be entirely neglected. Of course it must be understood that we are taking no account of the resistance which may be due to the stop valve or throttle valve. If these are properly proportioned, they will, when wide open, in no way affect the results. As regards the resistance of the cylinder ports, and what is known as "loss of head," we shall do no more than refer our readers to "Rankine on the Steam Engine," page 414. We are now dealing with steam pipes, not with cylinder ports.

It is very commonly assumed that when a very long steam pipe is used there must be a great difference between the pressure in the boiler and the cylinder. This assumption, we believe, if used in the absolute sense, to be altogether erroneous. It is of course quite possible to make a steam pipe so small, and so full of bends and sharp turns, that it will cause considerable resistance and consequent loss of pressure; and it will be found, we venture to say, in all cases where a considerable loss of pressure does really take place, that the steam pipes are made too small and that the velocity of the steam is over 100 ft. per second. The temptation to make long steam pipes too small is very great, because the cost of a considerable length of steam piping is not a trifle. When the piping is large enough no loss of pressure worth mentioning will take place, even though the pipe be two or three hundred yards long, so far as frictional resistance can affect the question. There is only one other cause of loss of pressure, and this is condensation in the steam pipe, and this must of necessity be almost wholly inoperative to the assumed end. A little reflection will show that the length of steam piping suspended in air required to condense steam nearly as fast as a boiler can supply it, would be enormous. It is impossible, in short, for a steam pipe of any reasonable length to have much less pressure at one end than the other, provided the velocity does not exceed 100 ft. per second. We may regard the effect of condensation as being the same as though a second engine were put on. If as much steam was condensed as was used by the engine, then the consumption of steam at the further end of the pipe from the boiler would be practically doubled, and the required velocity would then be 200 ft. per second instead of 100 ft.; that is to say, if the pipe were properly proportioned to supply the engine only in the first instance, there would in the second be a small loss of pressure due to the increased velocity of the steam required to make up for condensation; but this would not be due directly to condensation, but to the fact that the steam pipe was too small for its work. The remedy is obvious. Let the steam pipe be protected and the loss of pressure will become little or nothing. One of the best means of protection is to lay the steam pipe underground in large wooden troughs, waterproof if the ground be damp, the troughs to be filled with dry sawdust or fine dry sand. If this arrangement be inadmissable, then the pipes should be covered with felt, or some one or other of the various compositions for the purpose in the market. The loss by condensation may in this way be reduced to one or two per cent. of the whole quantity of steam used by the engine. A pipe 12 in. in circumference and 200 ft. long would have 200 square feet of surface, and the total quantity of steam which such a pipe would condense if exposed unlagged to air at 60 deg. would not exceed about 72 lbs. per hour. But the sectional area of such a pipe inside would be about 9 in. A cubic foot of steam would occupy 192 in., or 16 ft. of its length, and at 100 ft. per second, the tube would pass 6.25 cubic feet per second, or 22,500 cubic feet per hour. The weight of this steam, taking it at 50 lbs. pressure above the atmosphere, would be 4,017 lbs. Assuming that the engine used 60 lbs. per horse-power per hour, this would represent over 66 horse-power, and as the loss by condensation would not exceed 72 lbs., it will be seen that it is ridiculous to talk of condensation in the pipe as a cause of loss of pressure. In a word it may be stated that loss of pressure in a long steam pipe can only take place as a result of the frictional resistance of that pipe to the fluid moving within it; that sharp bends materially increase the resistance; but that if the pipe is tolerably straight and sufficiently large, the frictional resistance will be almost inappreciable; in no case can condensation be a cause of loss of pressure unless the pipe is exposed uncovered to rain, or water in some other form, and that the loss of pressure will then be due, not to condensation, but to the fact that those portions of the pipe near the boiler will be too small to supply the extra demand for steam at the other end of the pipe, unless the steam flows at such a velocity that the frictional resistance of the pipe will operate prejudicially. It is not to be denied, however, that in many instances in practice there is a very serious loss of pressure between the engine and boiler in long pipes. In all such cases, however, the pipes are too small for their work, or they are improperly fitted. We

can call to mind one which came under our own knowledge, where the difference in pressure between the boiler and the engine, with a 3-in. pipe about 12 ft. long, was as much as 12 lbs. The engine had only just been started; the stop valve was held to be guilty, and was changed for one larger. This did no good. Then new steam pipes were ordered, and when the old one was taken down it was found that the whole cause of the mischief lay in the fact that the man who put the pipes up, in making a flange joint, used a ring wrapped with tow and red lead. The inner diameter of the ring, instead of being 3 in., was little more than 1 in. The joint was remade as it should be, the pipes re-erected, and there was no more trouble. Nothing is more common at collieries and mines than the use of long steam pipes made of any kind of tubing at hand, and of varying diameter, but invariably too small. Then we hear of loss of pressure, and it is on no better basis than this that the whole theory of pressure being lost if a steam pipe is long has been built up. In designing steam pipes, as well as any other appurtenance of a steam engine, nothing is more easy than to make a mistake. If we can induce our readers to think twice before they settle the proportions of their steam pipes, our purpose in writing this article will have been served.

THE FORM AND CONSTRUCTION OF SEWERS.*

From "The Architect."

The author, after referring to the water, earth, and air systems of removing sewage, stated that when the water system is properly planned, executed, and taken care of, it works most satisfactorily, and that when there is deposit and smell at any part it is invariably caused by malformations, faulty execution, neglect, or the absence of some necessary appliance. As the water system derives the requisite power to remove the sewage matters from the form, fall, size, and construction of the channels, it is imperative that by no defect in these should any of this power be wasted or lost. At different periods various forms have been used for drains and sewers. The best is that of an egg, broad at the large end, and narrow at the small end, and this end placed downward. The egg-shape and the circle are now generally employed for large brick sewers, and the circle for pipe sewers and drains. Thirty years ago two large sized sewers were in use in the Westminster district. The form was nearly flat-bottomed, with upright sides and semi-circular crown; and the work was badly executed, especially in the inverts, where the bricks were usually laid dry. Before this form was introduced sewers were built with flat bottoms. Hundreds of miles of these sewers now exist in the metropolis, the bricks being porous, the mortar friable, the work rough, and the gradients extremely irregular. In the Westminster district there are 150 miles with slightly curved and flat bottoms. Through these the greater part of the sewage constantly leaked, saturating the ground, and leaving the solid matters behind upon the surface. During the author's examination of these sewers he found sewage deposits in nearly all of them, varying in depth from two or three inches to two or three feet. This was caused by the large width and flatness of the bottoms spreading and destroying the flow, by the bottoms permitting the liquids to pass through them like sieves, and by the street detritus collecting in small heaps opposite the gully drains and pressing back the sewage. Thus the sewers formed a network of extended cesspools, which were emptied at intervals when the accumulations stopped the house drains, and the decomposing filth sent up streams of noxious gases into the air through the gully and house drains, which at this time were defectively trapped and unventilated. The remedy for this state of things appeared to the author to consist in making the channels narrow, even, smooth and watertight, and in providing the inlets with syphon-taps and ventilating pipes. He took care that the sewers

*A paper read before the Society of Engineers, London, by John Phillips, C. E.

put in under his superintendence should be solidly and tightly constructed. This slightly increased the velocity of the flow, but the excessive width and flatness of the bottoms diffused the streams so much that they were unable to lift and carry away the sewage matters. What, therefore, appeared to the author necessary to ascertain was the form of channel that would give the sewage the utmost velocity, and the rate of velocity at which the sewage must travel to raise and keep the matters in suspension and carry them to the outfalls.

He therefore made four channels along the old sewers, namely, a semi-circle, an elliptic segment, a parabola, and a hyperbola, and for months he measured and computed the velocities of the sewage running in them. It resulted from his experiments that the velocity was greater in the elliptic segment than in the semicircle, in the parabola than in the elliptic segment, and in the hyperbola than in the parabola. This was evidently due to successively contracting the bottoms of the channel, which, by successively increasing the depth of the stream, increased its slope at the surface, and thus, by giving it greater gravitating energy, increased its velocity and scour. He also found that sharp curved side walls with a large batter resisted lateral pressure better than flat curved side walls with a small batter, and that a prolate elliptical arch sustained vertical pressure better and gave more headway than a semicircle. Combining these results, he produced an egg-shaped sewer, which was adopted by the Westminster Court of Sewers in place of the old form with a nearly flat bottom and upright sides. This was in 1846. Soon after this he introduced an egg-shaped sewer, with the same invert, but with a semicircular crown. This form has been in use ever since in the metropolis, as also throughout Great Britain, Europe, India, and America. The author stated that owing to the quantity of sewage running in the sewers each day, varying from a minimum to a maximum flow, the channels should be made in accordance with the increment of the flow, that is, parabolic or hyperbolic, and not semicircular. By this means the minimum flow, and the stream at all depths up to the maximum flow, would have much greater velocity. This applies to all channels for the conveyance of sewage from the smallest drain to the largest outfall sewers.

The construction of brick and concrete sewers was then reviewed. They should be built accurately to the inclination and curvature, thoroughly solid and watertight, and perfectly even, smooth and regular. By particularly attending to these essential points, distortion and leakage are prevented, and the flow is accelerated. Bricks only of the very best quality, and Portland cement, which is almost proof against the chemical action of sewage, should be used. Concrete sewers are jointless and non-absorbent, and are stronger and more durable than brick sewers. Three courses of solid fire-clay blocks in long lengths should be used along the bottoms. The use of hollow blocks at this part, where the weight of the sewer and of the ground pressing upon and against it is concentrated, is a mistake, for this weight causes such blocks to crack and break. Moreover, they let the sewage out of and the subsoil water into the sewer. Where the body of sewage or the inclination is small, the sand and other substances which are washed into the sewers become mixed with the excretæ, fat, hair, paper, and other matters, and form concrete masses along the bottoms, which no current or flush of water can tear up or remove. For this reason detrital substances should be kept out of sewers and drain channels as much as possible. This is to be done by making catch-pits under the sinks and gullies, and taking care to empty them after every rainfall. Much of the evils arising from deposit in and smell from drains and sewers is caused by not providing these necessary appliances, and in neglecting to employ them where they are provided. The author first introduced syphon-trapped catch-pits under the gullies in the metropolis in 1848, and they have been generally used in towns ever since. As sewage is charged to its maximum capacity with comminuted organic and inorganic matters, it must flow at a certain rate of velocity to hold the sediment in suspension and carry it with the detritus to the outfalls. From 1844 to 1846, inclusive, the author measured and computed the sewage running in the Westminster sewers, both where there was deposit and where there was none, and it resulted,

from his experiments, that where there was deposit the velocity of the flow was less, and where there was no deposit the velocity was more than 2½ feet per second. Whether the flow or the inclination was large or small, so long as the sewage travelled at this rate of velocity the sedimentary and other matters were completely carried away. This result threw a new light on the science of sewage. The author first enunciated this principle in 1847 before the Sanitary Commission. It was quoted by Beardmore, adopted by Bazalgette in arranging the gradients for the main drainage of the metropolis, and engineers have ever since regulated the inclination of sewers in accordance with it. Where the body of sewage or the inclination is sufficient to produce this velocity, there is no need to provide for flushing; but where the one or the other is insufficient to generate the required velocity, deposit will ensue and accumulate unless it is flushed away.

A quarter of a century ago the greater part of the sewers of the metropolis were found to be sewers of deposit. Ample data were then obtained from which a general plan could have been laid down for making nearly all of them self-cleansing with the common run of sewage. The flushing system, however, was adopted, and is still in use. At the present time there are about 600 miles of sewers in the metropolis which would choke up if they were not regularly flushed. It is a popular fallacy among the uninitiated that the main drainage has effectually improved these sewers. In no way have they been improved by it. Hence they accumulate deposit now just the same as they did before the main drainage was begun, and they will continue to do so until contracted hyperbolic channels are laid down along the old inverts. The author proposed this plan in 1847 before the Sanitary Commission, but a general system of flushing was adopted instead. The plan has since been tried in some deposit sewers, which have by its means been changed into self-cleaning sewers. About £330,000 have been expended during the last quarter of a century in flushing. This is at the rate of £13,200, or one penny per foot level, per annum. The cost of laying down new hyperbolic channels as proposed would be about 3*s.* 9½ *d.* per foot run, or £1,000 per mile. Consequently the cost of the 600 miles would be £600,000. The amount expended annually for flushing would pay off the principal and interest of this amount in thirty years, or the money could be raised from the coal tax. Stoneware pipes are generally made circular, but it would be a great improvement to make the inverts hyperbolic and the chevrons semicircular. The minimum flow would then have less frictional surface, more depth and more velocity, and the velocity at all depths up to the maximum flow would be greater. If the form which generates the utmost velocity is to decide which channel is best for the conveyance of sewage, then, unquestionably, the hyperbolic channel is far superior to the semicircular, and should be used instead. But it has been urged as an objection to employing pipes of any other shape than circular for sewers and drains that, owing to the distortion which takes place during the drying and burning of the clay, they cannot, while being laid, be made to fit each other so well at the joints as the circular pipes, which can be turned round until the convex distortion in one pipe fits the concave distortion in the other. Hence perfection of form, evenness of surface, and increase of velocity are sacrificed because of the distortion which is unavoidable in the manufacture of these pipes. Also, owing to the irregular shape of and large space in the sockets when the pipes are put together, they never fit each other so as to produce concentricity, but protrusions are formed round their interior, which may be seen by laying a few pipes together on a board. Moreover, owing to the difficulty of getting to the under side of the joints, they cannot at this part be made water-tight without great care and supervision. The gaping openings at the side and top of the joints also allow the cement used in stopping them to squeeze through, drop on the bottom, or form frills round the inside, causing obstructions and reducing the bore of the pipes. Another drawback to the production of even, regular, and efficient channels for the conveyance of sewage by stoneware pipes is their short length of two feet. Engineers should specify them three feet and even four feet long. The advantages would be that there would be a less number of joints, or rather points of leakage, the pipes could be laid truer

to the line and gradient, and the velocity of the sewage would be unchecked and increased. With a view to remedy the defects in the joints of those pipes, the author has recently invented a new joint, which can be easily made perfectly tight against leakage, and will ensure concentricity of the pipes, and of their being solidly laid. This invention he has no doubt will accomplish what has been so long desired, to make stoneware pipes concentric and watertight. Pipes, however, can be manufactured of Portland cement truer of shape, much longer, and consequently with fewer joints, and stronger and more durable than stoneware pipes. Portland cement sets and becomes intensely hard, which goes on increasing indefinitely. It also resists compressive and tensile strains much more than vitrified stoneware. On the Continent such pipes are largely used, and most excellent pipes they are. With Portland cement pipes, made as the author suggests, laid in straight lines to regulate inclinations, and tightly jointed as he describes, we should obtain perfectly formed sewers and drains, uniform of section, even of surface, and tight at the joints, which are the desiderata for channels for the conveyance of sewage.

THE NEW METHOD OF "GRAPHICAL STATICS."

By A. J. DUBOIS, C. E., Ph. D.

Written for Van Nostrand's Engineering Magazine.

The object of the following pages is to call more general attention to a new method for the graphical solution of statical problems, which has during the last ten years, mainly in Germany, been gradually developed and perfected, and which offers to the architect, civil engineer, and constructor a simple, swift, and accurate means for the investigation of a great number of practical questions. When once thoroughly understood and familiarized, it will be found greatly superior to the graphic methods at present in general use. Thus, for instance, in the determination of the *centre of gravity* and *moment of inertia* of areas and solids; of the resultant of forces either in space or in the same plane, and having the same or different points of application, as also in the resolution of forces generally, the method alluded to will be found of easy and universal application. When applied to determine the strains in the various members of a roof truss, bridge girder, or similar framed structure, it furnishes a system of "diagraming" which can be applied independently of any special assumptions as to load distribution, which gives the strain in each member by a single line, which is simple and rapid of execution, and which checks its own accuracy.* In its application to "*continuous girders*" it furnishes the *only* method of complete solution for variable loading, without calling in the aid of the higher analysis, or having recourse to intricate formulæ and wearisome calculations. Thus, a girder continuous over three or more supports, at different elevations, and sustaining a "concentrated load" at any point, can be investigated with nearly the same ease and accuracy as one resting upon only two supports. Here especially those already familiar with the analytical method can, by a union of the two, greatly shorten the time and labor usually consumed in such cases.

To Prof. Mohr, of the Stuttgart Polytechnicum,* the new method owes its origin, as well as many of its most important improvements and extensions. But it was not till 1866 that the complete and systematic presentation of the subject by Culmann† directed general attention to the subject, and excited general interest.

During the eight years which have since elapsed, the method has been considerably extended, notably in the treatment of continuous girders above referred to, and the new edition of Cullmann's original work, which is soon to appear,

* *Iron Bridges and Roofs*, Unwin. London, 1869; p 127.

* *Zeitschrift des hannov.* Arch. u. Ing. Ver. 1860 and 1868–70.

† *Die Graphische Statik.* Zurich, 1866.

and which has been so long promised, is looked forward to in Germany with considerable interest.

Admirable as Culmann's treatment of the subject undoubtedly is, still for a long time this interesting and useful method failed to meet with that appreciation and recognition from professional men to which it had such just claims; partly, perhaps, because of a natural disinclination in old practitioners to relinquish well known and familiar methods, and partly because the treatment of Culmann required for its comprehension a knowledge of the so-called "Modern Geometry," or *Theory of Transversals.*

This method of treatment is, however, by no means necessary. The system admits of a clear and logical development, which can be followed and apprehended by any one familiar with the elements of geometry as generally taught; and to give in just such a manner the outlines of the subject, indicating its most important applications, and thus to bring it within the reach of those in this country for whose benefit it seems so especially designed, is the purpose of these pages.

1. NOTATION, ETC.—In order that a force may be "given" or completely determined in its relations to other forces, we must know not only its *intensity*, but also its *direction*, and the position of its *point of application.* These three being known, the *geometrical* expression of our knowledge is very simple. We have only to assume a certain *length* as the *unit* of force, and then any force is at once given by the *length, direction, and position of a straight line.* This method of force representation is so obvious, that it is in fact used in mechanics, even where the treatment itself is essentially analytical.

Unless expressly stated, all the forces with which we have to do in these articles will be considered as lying and acting in the *same plane.* Graphically then, any force is completely determined by a straight line, the beginning of which represents the point of application, and the length and direction of which give the intensity and direction of the force.

We shall indicate a force in general by the letter P, its point of application by A. When we have several forces we represent the points of application by A_1, A_2, A_3, etc., and the *ends* of the corresponding lines by P_1, P_2, P_3, etc. The direction in which a force is supposed to act is thus unmistakably indicated.

When, however, lines representing several forces are laid off one after another, the beginning of each at the end of the preceding, it will be sufficient to put 0 at the beginning of the first, and 1, 2, 3, etc., at the end of each. No confusion can arise, as each force acts and reaches from the point indicated by the figure which is one *less* than its index, to the point indicated by that index.

When, finally, we designate a force by the two letters or figures which stand at the beginning and end, we shall always indicate by the *order* in which the letters or figures are written, the direction of action of the force, first naming the point of application, and then the end.

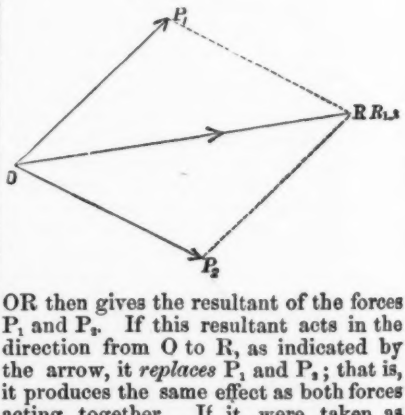
A force due to the composition of several forces, as P_1, P_2, P_3, we denote by $P_{1\text{-}3}$ or $R_{1\text{-}3}$. Thus $R_{1\text{-}3}$ denotes the *resultant* of the forces P_1, P_2, and P_3.

CHAPTER I.

FORCES IN THE SAME PLANE—COMMON POINT OF APPLICATION.

2. If two forces, P_1 and P_2, given in direction and intensity by the lines OP_1 OP_2 [Fig. 1], have a common point of application O, the resultant $R_{1\text{-}2}$ is found by the well known principle of the "parallelogram of forces," by completing the parallelogram as indicated by the dotted lines, and drawing the diagonal.

FIG. 1.



OR then gives the resultant of the forces P_1 and P_2. If this resultant acts in the direction from O to R, as indicated by the arrow, it *replaces* P_1 and P_2; that is, it produces the same effect as both forces acting together. If it were taken as acting in the opposite direction—*i.e.*,

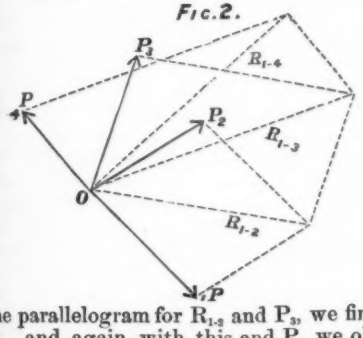
from O outwards, *away* from R—it would hold the forces P_1 and P_2 in *equilibrium*.

Now, we see at once that it is *unnecessary to complete the parallelogram*. It is sufficient to draw from the end of the force P_2 the line P_2 R *in the same direction that* P_1 *acts in*, and make it equal and parallel to P_1. The point R thus found is the end of the resultant R, or is a point upon the direction of the resultant prolonged through O.

As to the *direction* of action of the resultant. If we follow round the triangle from O to P_2 and from P_2 to R and R to O—*i.e.*, if we follow *round in the direction of the forces*—the direction for the resultant from R to O thus obtained is, as we have already seen, the direction necessary for *equilibrium*.

3. If, instead of two forces, we have three or more, as P_1, P_2, P_3, P_4 [Fig. 2] we still have the same construction. Thus completing the parallelogram for P_1 and P_2, we find $R_{1\text{-}2}$. Completing

FIG. 2.



the parallelogram for $R_{1\text{-}2}$ and P_3, we find $R_{1\text{-}3}$, and again, with this and P_4 we obtain $R_{1\text{-}4}$. Again, we see it is unnecessary to complete all the parallelograms. We have only to draw lines P_1 $R_{1\text{-}2}$, $R_{1\text{-}2}$ $R_{1\text{-}3}$, $R_{1\text{-}3}$ $R_{1\text{-}4}$, parallel to the forces P_2 P_3 and P_4 respectively, and equal in length to the intensities of these forces, and then, no matter what may be the number of forces, the *line drawn from the point of beginning to the end of the last line laid off* will give the intensity and position of the resultant. As to direction, the same holds good as before.

If the end of the last line laid off should coincide with the point of beginning, there is, of course, *no* resultant, and the forces themselves are in equilibrium.

The polygon formed by the successive laying off of the lines parallel and equal to the forces, we call the "*force polygon*." Hence we have the following principles established:

If any number of forces having a common point of application and lying in the same plane, are in equilibrium, the "force polygon" is closed.

If the "force polygon" is not closed, the forces themselves are not in equilibrium, and the line necessary to close it gives the resultant in intensity and direction.

This resultant, if considered as acting in the direction obtained by following round the "force polygon" with the forces, will produce equilibrium—acting in the opposite direction, it replaces the forces.

The resultant thus found in intensity and direction can be inserted in the *force diagram* at the common point of application.

5. Thus, required the position, intensity, and direction of the resultant of the forces P_1, P_2, P_3, P_4, P_5.

These forces are given in position, direction, and intensity by the *force diagram*, Fig. 3 (*a*). The resultant of all these forces must have of course the same point of application A as the forces themselves—it remains to find then its relative position and the direction of its action, so that we may properly insert it in the *force diagram*.

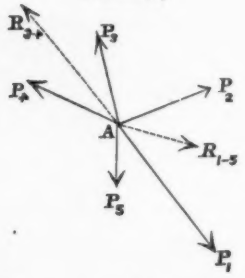
We have simply to draw the *force polygon*, Fig. 3, (*b*) by laying off successively O, P_1, P_2, P_3, etc., equal, parallel, and in the same direction as the forces P_1, P_2, etc., as given by Fig. 3 (*a*). Then the line P_5 O necessary to close the force polygon gives the intensity of the resultant, and in order to replace $P_{1\text{-}5}$ it must act in the *direction from O to* P_5; *i. e.*, contrary to the order of the forces. If then in Fig. 3 (*a*) we draw A R equal and parallel to O P_5, we have the resultant applied at the common point of application A, and given in position, intensity, and direction.

Moreover, it is evident that *any diagonal* of the force polygon as $R_{2\text{-}4}$ [Fig. 3 (*b*)] is the resultant of $P_{2\text{-}4}$, and acting in the direction from P_4 to P_2, it holds $P_{2\text{-}4}$ in *equilibrium*. But it is also the resultant of P_1, P_2, P_5, and $R_{1\text{-}5}$, and acting in the same direction as before, it *replaces* these forces. The force polygon thus shows that the force which *replaces* P_1, P_2, P_5, and

$R_{1\text{-}4}$, at the same time holds P_3 and P_4 in *equilibrium*, just as it should be.

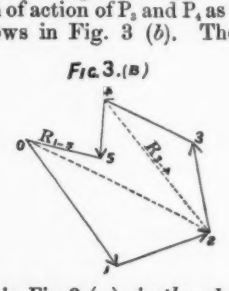
If, on the other hand, we had originally only P_1, P_2, $R_{3\text{-}4}$, P_3, and $R_{1\text{-}4}$ forming a system of forces in equilibrium, we could *decompose* $R_{3\text{-}4}$ into two components by simply assuming any point as P_3 [Fig. 3 (*b*)] and drawing P_3 P_4 P_3 P_3. Then following round this new polygon in the direction

FIG. 3 (A)



of the forces, or, what amounts to the same thing, taking the direction of the components P_3 P_4, *opposed* to the direction of $R_{3\text{-}4}$ for equilibrium, we obtain the direction of action of P_3 and P_4 as shown by the arrows in Fig. 3 (*b*). These forces

FIG. 3. (B)



inserted in Fig 3 (*a*), *in the place* of $R_{3\text{-}4}$ and in these directions, will not disturb the equilibrium.

Hence, *any diagonal in the force polygon is the resultant of the forces on either side, holding in equilibrium those on one side and replacing those on the other, according to the direction in which it is conceived to act.*

Also, *any force or number of forces may be decomposed into two others in any desired direction, by choosing a suitable point in the plane of the force polygon and drawing lines from this point to the beginning and end of the force or force polygon.*

6. IT MATTERS NOT IN WHAT ORDER WE LAY OFF THE FORCES IN THE CONSTRUCTION OF THE FORCE POLYGON.

Thus, in Fig. 1, whether we draw from the end of P_2 the line P_2, $R_{1\text{-}4}$ equal and parallel to P_1 or from the end of P_1 the line P_1 $R_{1\text{-}2}$ equal and parallel to P_2, in either case we obtain the same resultant and the same direction for the resultant. But by a similar change of two and two, we can obtain any order we please. For example, we lay off in

FIG. 3. (C)

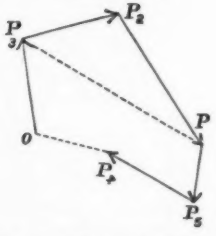


Fig. 3 (*c*) the same forces in the order $P_3P_2P_1$ P_5 P_4, and obtain precisely the same resultant, in the same direction as before. For, the resultant of P_3 and P_2 must be the same as that of P_2 and P_3 in the first case. The resultant of $R_{3\text{-}2}$ and P_1 must then be the same in both polygons, and so on.

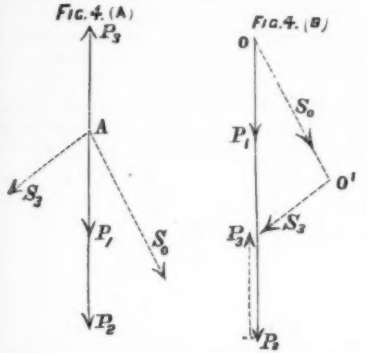
Generally, then, no matter what the order in which the forces are laid off, the line necessary to close the force polygon is the resultant of the forces, and the diagonals of the force polygon give us the resultants of the forces on each side.

By assuming a point at pleasure, and drawing lines from this point to the beginning and end of any side of the force polygon, and taking the direction of these lines *opposed* to the direction of that side, we can *decompose* any force in the force polygon into its components. Thus the force polygon gives us complete information as to the action of the forces.

7. IF THE FORCES ACT IN THE SAME STRAIGHT LINE, the force polygon of course becomes a straight line also, and the resultant is the sum or difference (algebraic sum) of the forces.

Thus, if we have P_1, P_2, P_3 all acting at the point A, as shown by the force diagram Fig. 4 (*a*), we form the force polygon by laying off from O Fig. 4 (*b*) the intensity of P_1, from the end of this line P_1 P_2 equal to A P_2 and from P_1, P_2, P_3 equal to A P_3. Then the line necessary to close the poly-

gon is evidently O $P_3 = P_1 + P_2 - P_3$. A single force acting then at A in the direction of and having the intensity repre-



sented by the line O. P_3 would replace P_1, P_2, and P_3. If acting from P_3 to O, it will produce equilibrium.

If we again choose an arbitrary point as O' [*we shall hereafter call this point the "pole" of the force polygon*], and draw lines S_0 S_3 from this *pole* to the beginning and end of the force polygon, we can decompose the resultant into two forces in any required direction. If the resultant is supposed to act down, then the arrows show the direction in which these components must act in order to *replace* the resultant. If then at A we draw lines parallel and equal, we have these components in position, direction, and applied at the common point of application.

PRACTICAL APPLICATIONS.

8. Simple and even self-evident as all the preceding may seem, we have already acquired all the principles requisite for a rapid, accurate, and very elegant method of finding by diagram the strains in the various members of all kinds of framed structures, such as roof trusses, bridge girders, cranes, etc., no matter how complicated the structure, or what special assumptions are made as to the loading, provided only, that all the exterior forces are known. A complicated or unsymmetrical arrangement of parts increases greatly the labor of calculation, but has no effect upon the ease or accuracy of the graphical method. The method moreover checks its own accuracy, does not accumulate errors, and shows in one view the *relation* of the strains to each other, and the variations which would be caused by a change in the manner of load distribution, or in the form of construction.

As this method is not as well known as it deserves to be, it will perhaps be of advantage to pause for a moment in the development of our subject, and make this direct application of the principles already established.

BRACED SEMI-ARCH.

9. Stoney, in his "Theory of Strains," Vol. I., page 123, gives the following example of a "braced semi-arch," represented by Fig. 5. The dimensions are as follows: projecting portion, 40 ft., long 10 ft. deep at wall. Lower flange, circular, with a horizontal tangent 2 ft. below the extremity of girder. Radius of lower flange, 104 ft. Load uniform and equal to one ton per running foot supposed to be collected into weights of 10 tons at each upper apex, except the outer one, which has only 5 tons.

Fig. 5 shows the Arch drawn to a scale of 10 ft. to an inch.

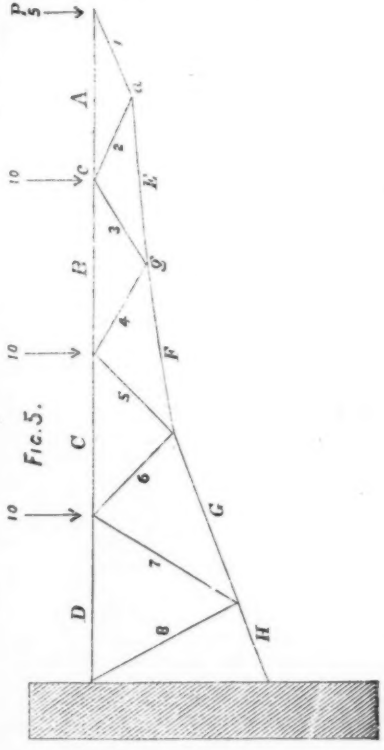
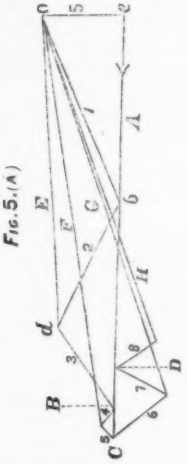


Fig. 5.

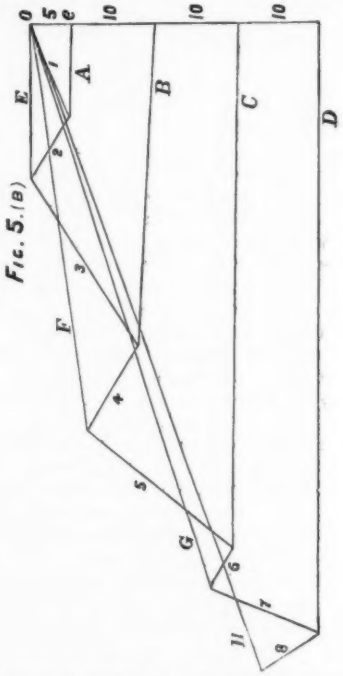
This scale is too small in this case to ensure good results; in general the larger the scale to which the *frame* can be drawn, the better; but for the purpose of illustration it will answer well enough. With a large scale for the *frame diagram*, a scale of 10 tons to an inch will in general be found to answer well. Fig. 5 (*a*) gives the strains in the various members to a scale of 10 tons to an inch and Fig. 5 (*b*) 20 tons to an inch; the first for the load at the extremity alone, the second for a uniform load.

Fig. 5 (*a*) is thus obtained. We first lay off the weight, 5 tons, to scale, in the direction in which it acts; *i.e.*, *downwards*. Now this weight and the strains in diagonal 1, and flange A, are in *equilibrium;* therefore by article (4) the force polygon must close. Drawing lines therefore from the ends of the line representing the weight 5 tons, parallel to these pieces and prolonging them to their intersection, we obtain the strains in A and 1. Commencing with the beginning of the weight line and following *down* around the triangle thus formed, we find that A acts from right to left, as shown by the arrow. A acts then *away* from the apex; it is therefore in *tension*. Diagonal 1 acts *towards* the apex and is *compressed*.



We pass now to apex *a*, of the frame. Here we have the strains in E and diagonals 1 and 2, and these three strains hold each other in equilibrium. The strain in 1 we have already, and know it to be *compressive*. We have then simply to draw lines parallel to E and 2, and follow round the triangle, to obtain the intensity and quality of the strains in E and 2. We must remember that as 1 is in compression, and we are now considering apex *a*, we must follow round from *o* to *b* in Fig. 5 (*a*), and so round. We thus find 2 acting *away* from apex *a* and therefore in *tension*, and E acting towards this apex, and hence *compressed*.

Pass now to apex *c*. We have the strains in A and 2 in equilibrium with B and 3. [No weights are supposed to act except the one at the end.] But A and 2 we already have. We draw 3 and B. Diagonal 2 has been found to be in tension. With reference to apex *c* it must therefore act *away* from *c*; *i. e.*, from *d* to *b* in the force polygon. This is sufficient to give us the hint how to follow round. We pass from *d* to *b* for 2, from *b* to *e* for A, then from *e* to B and from B to *d* for B and 3. B is therefore *tension* and 3 *compression*. And so we proceed. For the next apex *g*, we have E and 3 in equilibrium with F and



4. We draw parallels to F and 4 so as to close the polygon of which we have already two sides, E and 3, given, and remembering that as 3 is in compression and must therefore act *towards g*, we follow round the completed polygon with this to guide us, and find 4 *tension* and F *compression*. Thus we go through the figure, and when all is ready we can scale off the strains. The strains in the lower flanges it will be observed all radiate

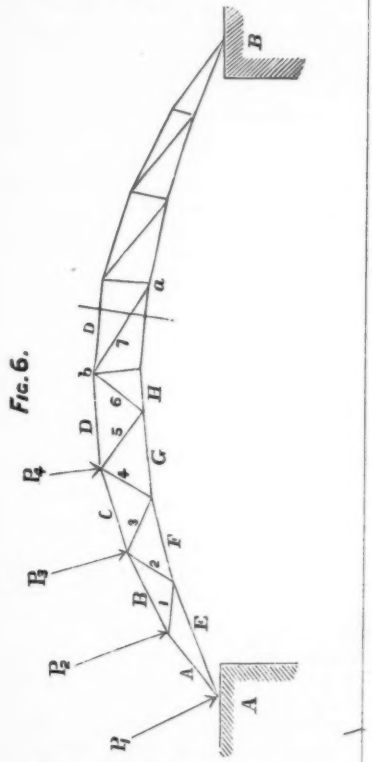


Fig. 6.

from *o*. The upper flanges are all measured off on the horizontal *e* C, and the diagonals are the traverses between. We see at once that however irregular the structure, we can always easily and readily determine the strains at any apex, *provided no more than two unknown strains are to be found*. If more than two pieces, the strains in which are unknown, meet at an apex, we can evidently form an indefinite number of closed polygons. The problem is indeterminate, and the structure has unnecessary or superfluous pieces.

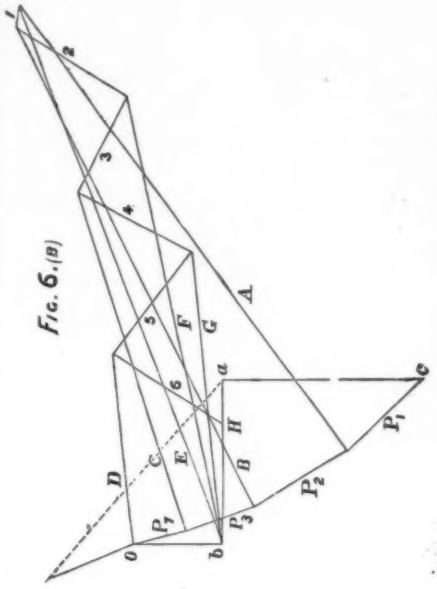


Fig. 6. (B)

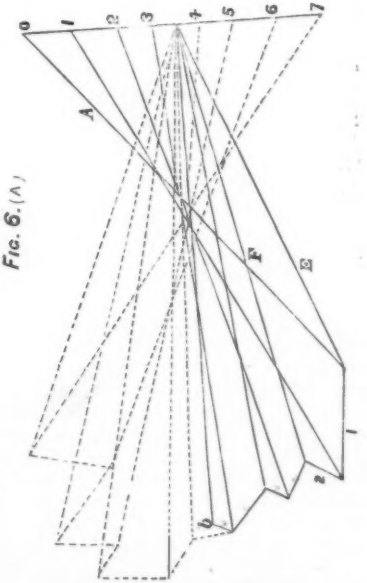


Fig. 6. (A)

Fig. 5 (*b*) gives the strains for a uniform load, taken, for convenience of size,

to a scale of 20 tons to an inch. Here until we arrive at apex *c* of the frame the strains are evidently the same as before. Observe the influence of the weight at *c*. Here we have the strains in A and 2 given in the diagram, in equilibrium with B, 3 *and the known weight* acting at *c;* viz., 10 tons. We lay off therefore 10 tons *downward* from *e* Fig. 5 (*b*), and follow *down* from *e* around the polygon. We thus find B tension and 3 compression. Then 4 and F are found as before for apex *g*, 4 tension and F compression; and then we come to the next apex and the *next weight*. This is laid off downwards from the end of the preceding, and then we follow round, finding C tension and 5 compression; and so on.

10. As another example, let us take the

ROOF TRUSS,

given in Fig. 6. This truss is given by Stoney, Vol. I., page 128. Dimensions: span, 80 ft.; rise of top and bottom flanges, 16 and 10 ft. respectively. Radii, 58 and 85 ft. The figure shows two different kinds of bracing. In the left-hand part the extreme bay of the lower flange is half as long again as the others. The upper flange is divided into 4 equal bays. In the right-hand section, both flanges are divided into 4 equal bays, and every alternate brace is therefore nearly radial. Each upper apex in both cases is supposed to sustain a weight of one ton.

The strains in the various pieces are given in Fig. 6 (*a*).

We form the force polygon by laying off the weights from 0 to 7 and then laying off the reactions 3.5 apiece, upwards, we come back to 0, and the force polygon is closed as it should be, since the sum of the reactions must be equal and opposite to the sum of the weights. Starting then with the reaction at the left support A, we go through from apex to apex in a manner precisely similar to the previous case. The operation is so simple that it is hardly necessary to detail it again, but we recommend the reader to go over it with the aid of Fig. 6 (*a*), lettering the figure as he proceeds. The dotted part gives the strains for the right-hand half.

DIAGRAM FOR WIND FORCE.

11. It is of considerable importance to investigate the influence of a partial load, such as that caused by the wind blowing on one side of the roof, and this by the aid of our method we can easily do.

From the experimental formulæ of Hutton,*

$$P_n = P \sin i \, {}^{1.84 \cos i - 1}$$
$$P_h = P \sin i \, {}^{1.84 \cos i}$$
$$P_v = P \cot i \sin i \, {}^{1.84 \cos i}$$

where P is the intensity of the wind pressure in lbs. per sq. ft. upon a surface perpendicular to its direction, *i* is the inclination of any plane surface to this direction; P_n is the normal pressure, P_h the horizontal component of this normal pressure, and P_v its vertical component.

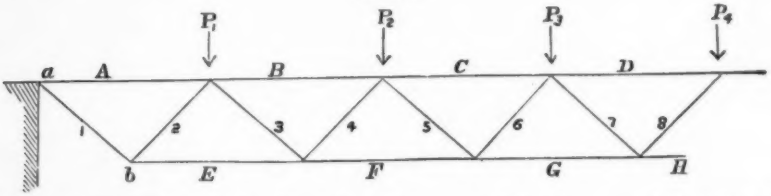
That is, if the wind blows horizontally, P_h is the horizontal and P_v the vertical component of the pressure on the roof. If we take P=40 lbs., which probably allows sufficient margin for the heaviest gales, we have the following values of the normal pressure and its components for various inclinations of roof surface:

Angle of Roof.	Lbs. per square foot of surface.		
	P_n	P_v	P_h
5°	5.0	4.9	0.4
10°	9.7	9.6	1.7
20°	18.1	17.0	6.2
30°	26.4	22.8	13.2
40°	33.3	25.5	21.4
50°	38.1	24.5	29.2
60°	40.0	20.0	34.0
70°	41.0	14.0	38.5
80°	40.4	7.0	39.8
90°	40.0	0.0	40 0

The load at each joint may be taken as equal to the pressure of the wind striking a surface whose area is equal to that portion of the roof supported by one bay of the rafter, and inclined at the same angle as the tangent to the rib at the joint. Thus we can calculate P_1, P_2, P_3, and P_4, [Fig. 6], resolve these forces into their horizontal and vertical components, and find the reactions at the supports as well as the horizontal force at the left abutment, which in our construction is supposed to be fixed. Should the wind be supposed to blow from the right side, the strains would be entirely different, and it would be necessary to form a second diagram. Each piece must be proportioned to resist the strains arising in either case. The forces $P_{1\text{-}4}$ and their horizontal and vertical components, as also the reactions, being known, we can now form the force polygon.

**Iron Bridges and Roofs.* Unwin. P. 120.

FIG. 7.



In Fig. 6 (*b*) we lay off the forces $P_{1\text{-}4}$, make *a c* equal to the vertical reaction at A, *a b* = the sum of the horizontal components, or the horizontal force at A, and *o b* the vertical reaction at the right support. This last line should close the force polygon and bring us back to *o*.

Now starting at the left support, we have the vertical reaction *a c*, the horizontal force *a b*, and the wind force P_1, in equilibrium with A and E. Closing the polygon by lines parallel to A and E, we obtain the strains in these pieces, E tension and A compression. At the next apex we have A and P_2 in equilibrium with 1 and B. Completing the parallelogram, we find 1 compression and B compression. At the next apex 1 and E are in equilibrium with 2 and F, and we find F and 2 tension, and so on. The upper flanges are in compression and start from the ends of the forces P_1, P_2, etc. The lower flanges radiate from *b*. If we were to carry out the construction for the rest of the frame, the upper flanges after D would radiate from *o*.

A comparison of Fig. 6 (*a*) and (*b*) shows that whereas under uniform load the strain in 1 is *tension*, for wind force the same brace is in *compression*. In fact in the first case *all* the braces are in tension, while in the second 1, 3, and 5 are compressed, and 3 and 5 quite severely. The strains in the bracing generally are much greater in the second case.

Were we to consider the wind as blowing from the other side, or what is the same thing, suppose the right end fixed and the left supported on rollers, then the horizontal reaction *a b* will be applied at the right abutment. In this case the lower flanges will radiate from *a* instead of *b*, and the first upper flange will start from *o*. Supposing the first two lines of this new diagram drawn, as indicated by the dotted lines, and following round from *b* to *o*, and so round to *a* and back to *b*, it may easily happen that the last upper flange is in *tension* and the last lower flange in *compression*; that is, a *complete reversal of the ordinary condition of strain*.

For an excellent presentation of the above method, we refer the reader to *Iron Bridges and Roofs*, by W. C. Unwin. Pp. 128–140. The above method is there referred to as "*Prof. Clerk Maxwell's Method*," and as such is known and used in England.*

FIG. 7.(A)

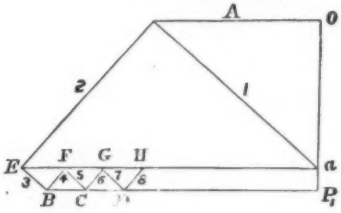
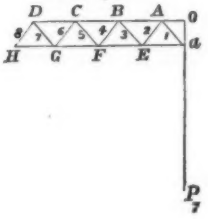


FIG. 7.(B)



BRIDGES.

12. For *bridges* the strains due to a *uniform* load are of course easily found. In most cases a *rolling load* can be managed also *without* making a separate diagram for each position of the load. Thus, if we

* Phil. Mag., April, 1864, and a Paper read before the British Association for the Advancement of Science, by Prof. Maxwell, in 1874.

For a thorough application of the method to Roof Trusses, see also an article by Skiesz, *Der Civilingenieur*, 20 *Vol., Viertes Heft.*

diagram the strains for the load at the first and last apex, the strains due to intermediate loads will be multiples or submultiples of these. A calculation for a simple Warren girder of small span, and a consideration of the reaction for each position of the load, will at once illustrate what is meant. [Compare Stoney, *Theory of Strains*. Pp. 99-111, Vol. I.]

Thus Stoney, in his *Theory of Strains*, Vol. I., p. 99, gives the girder represented in Fig. 7, span, 80 ft., depth of truss, 5 ft., 8 equal panels in upper flange, 7 in lower.

For the first weight of 10 tons, P_1, the strains are given by Fig. 7 (*a*) to a scale of 10 tons to an inch. We form first the *force polygon* by laying off from *o* 10 tons, to P_1. From the end of this line we lay off upwards the reaction at right abutment=$\frac{1}{8}$ of 10 tons, or 1.25 tons; and then the reaction at the left abutment=$\frac{7}{8}$ of 10 tons, back to *o*, thus closing the force polygon. [Note.—In *any* structure which holds in equilibrium outer forces, the force polygon must close. If it does not, there is no equilbrium, and *motion* ensues.] Commence with the reaction at *a* in the frame diagram, Fig. 7, because here we have a known reaction, *oa* (force polygon), and only *two* unknown strains to be determined. Drawing lines parallel to A and 1, we obtain the strains in A and 1. Then pass on to apex *b*. With the now known strain in 1, we can determine 2 and E.

Passing now to the next apex, we have A and 2 known, and *also the weight* P_1. Join therefore P_1 and E [Fig. 7 (*a*)] by lines parallel to B and 3. B and 3 are both in compression. We find diagonal 2 also in compression, and 1 tension. That is, *the diagonals under the weight are compressed*, as evidently should be the case. From 4 on we have tension and compression alternately.

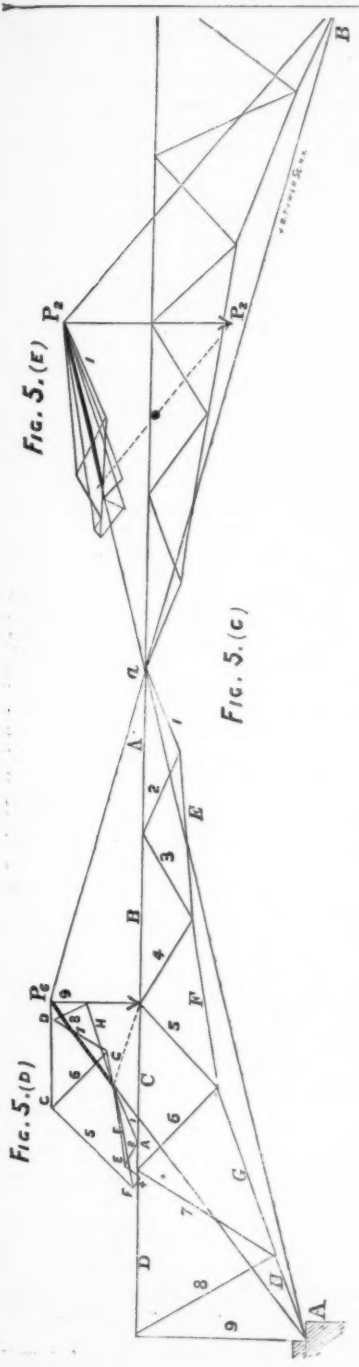
Fig 7 (*b*) gives the strains due to the *last* position of the load P_7. The strains in the diagonals are evidently all equal, and alternately tension and compression.

It is not necessary to construct more than these two diagrams. From these alone we can determine the strains for any intermediate weight. Thus scaling off the strains in Fig. 7 (*a*) and (*b*), we can tabulate them under P_1 and P_7, as shown by the table. Now the reaction at the left abutment due to P_6 is *twice* as great as that due to P_7. Hence the values in the column for P_6 will be twice as great; in the column for P_5 three times as great, and so on. For similar reasons the strain in 5 for P_3 will be twice that for P_1. In column P_2, then, from 5 down we multiply the strains in P_1 by 2. In P_3 from 7 down by 3. Thus we fill out the table of strains completely, and find the maximum tension and compression. A similar procedure will give the flanges.

Diagonals.	P_1	P_2	P_3	P_4	P_5	P_6	P_7	C	T
1.....	—12.4	—10.6	— 8.9	— 7.1	— 5.3	— 3.5	— 1.8	.....	—49.6
2.....	+12.4	+10.6	+ 8.9	+ 7.1	+ 5.3	+ 3.5	+ 1.8	+49.6	.....
3.....	+ 1.8	—10.6	— 8.9	— 7.1	— 5.3	— 3.5	— 1.8	+ 1.8	—37.2
4.....	— 1.8	+10.6	+ 8.9	+ 7.1	+ 5.3	+ 3.5	+ 1.8	+37.2	— 1.8
5.....	+ 1.8	+ 3.5	— 8.9	— 7.1	— 5.3	— 3.5	— 1.8	+ 5.3	—26.6
6.....	— 1.8	— 3.5	+ 8.9	+ 7.1	+ 5.3	+ 3.5	+ 1.8	+26.6	— 5.3
7.....	+ 1.8	+ 3.5	+ 5.3	— 7.1	— 5.3	— 3.5	— 1.8	+10.6	—17.7
8.....	— 1.8	— 3.5	— 5.3	+ 7.1	+ 5.3	+ 3.5	+ 1.8	+17.7	—10.6

APPLICATION TO AN ARCH.

13. For a "braced arch" (Stoney, p. 136) as represented in Fig. 5 (*c*), the strains in every piece due to any load are in similar manner easily found by first finding the components of the load acting at the



abutments, and then proceeding as above. Thus for a load P_2, the left half of the arch is in equilibrium with the forces acting upon it; viz., a horizontal and a downward force at *a*, and a horizontal and an upward force at A. The resultant of the forces at *a* must then pass through, and be equal and opposite to the resultant at A. The resultant at the right abutment must pass through that abutment, and also the intersection of P_2 with A *a*. So for any other force, as P_6, we have simply to draw B *a* to intersection with P_6, and then P_6 A. We can now decompose P_6 or P_2 along the resultants through the abutments. Thus resolving P_2 along A *a* and P_2 B, we find the force acting at *a*. This force resolved into A and 1 gives the strains on these pieces both compressive. Passing then to the next apex, we obtain the strains in 2 and E. Then to the next, and we get 3 and B, compression and *tension* respectively, and so on, as shown by diagram, Fig. 5 (*e*), which, it will be seen at once, is similar to Fig. 5 (*a*), already obtained for the "semi-arch," except that the strain in A is less than for the semi-arch and compressive, while B *c* and D are in tension. The reason is obvious. At *a* [Fig. 5 (*c*)] the resultant lies *between* A and 1, and therefore causes compression in both, while it passes outside of the arch entirely, to the right of the apex for diagonals 3 and 4, and hence causes tension in B *c* and D. Fig. 5 (*d*) gives the strains due to P_6. Here the resultant or reaction at A is first found and resolved into *g* and H, and then we go through the frame as before. We see that 4 and 5 under the load are both compressed, that E and F are in tension and G and H, as also the entire upper chord, in compression. The work checks from the fact that the line closing the polygon formed by E and 2 should be exactly parallel to and give the strain in diagonal 1, or A and 1 should be in equilibrium with the resultant through *a* [see Fig 5 (*d*)].

In every case of the kind we first, then, have to draw the *frame diagram*. Then lay off the *force polygon* which should close. Finally we construct the *strain diagram*. The frame diagram should be taken to as large a scale as possible consistent with reasonable size, and the scale for the force and strain diagrams as *small* as possible, consistent

with scaling off the strains to the requisite degree of accuracy. A small frame diagram does not give with the proper accuracy the relative positions and inclinations of the various pieces, so as to ensure the proper direction for the lines of the strain diagram. A slight deviation from parallelism causes sometimes considerable variation. Nevertheless with practice, care, and proper instruments the accuracy of the method is surprising; even in complicated structures, the variation resulting from performing the operation *twice* being inappreciable. Every symmetrical frame gives also a symmetrical strain diagram, and the accuracy of the work is tested at every point by this double symmetry, and finally by the end or last point of the second half, exactly coinciding with the last point of the first half. Thus in Fig. 6 (*a*), if we had but one system of triangulation carried through the frame, the strain diagram for the right half would be precisely similar and symmetrical to that already found for the first, and the end of the last line would fall, or should fall, *precisely* upon the point *b* of the first. If it does not, and the error is too great to be disregarded, by checking corresponding points in each half, we can find the point where the error was committed. In any case *errors do not accumulate*. Thus, armed with straight edge, scale, triangle, and dividers, we can attack and solve the most intricate problems, without calculation or tables, with ease, accuracy, and great saving of time.

METHOD OF SECTIONS.

14. The results obtained by the above method are best checked in general by Ritter's "method of sections," [*Dach und Brucken Constructionen*]. This consists in supposing the structure divided by a section cutting only *three* pieces. We can then take the intersection of *two* of these pieces as a centre of moments, and the sum (algebraic) of the moments of all the exterior forces, such as reaction, loads, etc., upon one of the portions into which the structure is divided by the section, with reference to this centre of moments, must be balanced by the moment of the strain in the third piece, with reference to this same point. Thus in Fig. 6., Pl. 2., required the strain in D. Take a section through D 7 and H (right half of Fig.) and let *a* be the centre of moments. The moments of the strains in 7 and H are of course zero, since these pieces pass through *a*. The moment of the strain in D with reference to *a* must then be balanced by the sum of the moments of the outer forces acting upon the portion to the left (or right) of the section.

Thus, strain in D multiplied by its lever arm with respect to *a*, is equal to moment of reaction at A, minus sum of the moments of loads between A and *a*, all with reference to *a*. If we take rotation in the direction of the hands of a watch as *positive*, and we find the moment of strain in D *negative*, it shows negative rotation about *a*, and the strain in D to resist this rotation must act *away* from *b*, or be tensile. If the resultant rotation of the outer forces is on the other hand positive, the strain in D must act *toward b*, and D is therefore compressed.

This method of calculation, it will be observed, is both simple and general. It can be applied to any structure, when the outer forces are completely known, and only three pieces are cut by the ideal section.

15. It is unnecessary to give further applications of our graphical method. The reader can easily apply it for himself to the "bowstring girder," bent crane, etc., and satisfy himself as to its accuracy, and the ease with which the desired results are obtained.

Enough has been said to indicate the many important applications which even at the very commencement of our development of the graphical method we are enabled to make, and here we shall close our discussion of forces lying in the same plane and having a common point of application. As we pass on to forces having *different* points of application, we shall have occasion to develop new principles and relations not less fruitful and useful in their practical results.

TELEGRAPH cables have been laid during the year between Jamaica and Porto Rico, and another short West Indian section, also between Constantinople and Odessa, between Zante and Otranto, and between Barcelona and Marseilles. The amount of mileage added to the submarine system has been very great.

MECHANICAL ENGINEERING.*

From "Engineering."

WHAT is the profession of a mechanical engineer? What is meant by "engineering?" That question was put, and it was answered many years ago, by a man whose works on engineering subjects are text-books even at the present day. I mean by Tredgold, who for the Institution of Civil Engineers gave this definition, that "engineering is the art of directing the great sources of power in nature for the use and convenience of man." Accepting this definition, let us see whether mechanical engineers have to any and to what extent carried out and fulfilled the obligations they took upon themselves when they became members of a profession which exercises such an art. I believe in answering that question we may, without boasting, say that mechanical engineers have, to a very large extent, fulfilled the obligations imposed on them by their profession. Let us review, as briefly as possible—so briefly indeed as to make the review little more than a list of the names of the subjects we shall notice—what has been done by the mechanical engineer. Happily for my purpose, we may confine our thoughts to a limited range of time, for in our profession, unlike that of the sculptor, the painter, or the architect, we have not to go back to past ages to find its triumphs—in fact, so little is to be gleaned from antiquity that I will not be tempted even by the name of Archimedes to advert to ancient engineering, but I will at once limit myself to a time so recent that it shall not carry us back to a date anterior to the lives of some of our present members, not anterior indeed to the lives of two of our past Presidents—Sir William Fairbairn and Mr. Robert Napier—both gentlemen who happily have contributed their fair share, and more than their fair share, to engineering progress. I will even take a shorter period than that included in the lives of our venerable friends, and will ask you to bear with me no longer than while I mention some few of the leading mechanical matters belonging to the nineteenth century only. To commence with that which is still the masterpiece of mechanical engineering, the steam-engine, I cannot say that it has been invented within this period, because doubtless it existed some little time before, not only for pumping purposes, but also to a very small extent for manufacturing purposes; but I may safely say that its practical application to these latter purposes has taken place within this century. Steam navigation is of even more recent origin; while the beginning of railways is, to men of my age, as it were a thing of yesterday; and the establishment of the electric telegraph is within the recollection of all but our youngest members. The science of sanitary engineering, although claimed, and perhaps properly claimed, by the civil engineer, depends so largely, especially in those parts of it which relate to the distribution of water, and to warming and ventilation, upon the aid of the mechanical engineer for pumping engines and other purposes, that it demands to be mentioned among the matters connected with our profession, as does also, which is almost a branch of sanitary engineering, the distribution of light by those gas works which, from first to last, are the product of the mechanical engineer's skill. The supplying of water by the aid of the mechanical engineer dates, it is true, from long before the commencement of this century, but the steps that have been made towards the perfecting of such a supply are so great that the matter may almost be treated as if it were entirely within the period of which I am speaking; while the practical manufacture and transmission, though not the very first production of gas, are quite within that period; as is also (when considered as a science) the getting rid of our sewage. But to the mechanical engineer we owe not only the laying on of light, as that word is ordinarily understood, but we owe to him the greatest improvements in laying on light to the mind, for we owe to him the steam printing-press, a machine which has developed from the early inventions of the father of one of our oldest and most distinguished

*Inaugural address before the Institution of Mechanical Engineers by the President, F. J. Bramwell.

members, one of the founders of this institution, Mr. Cowper, to the admirable machine by which *The Times* newspaper has for some years past been printed; and if the mechanical engineer had done no more than invent the steam printing-press, he would be justly entitled to the gratitude of the whole world. But the steam printing-press would have been a useless implement if paper had not been forthcoming in proper quantity and in proper form. Hand-made paper, it is true, might have sufficed, and did suffice for earlier constructions of printing machines; but the machine-made paper, another invention of the period under consideration, is, as you all know, an indispensable adjunct of *The Times* printing machine, as one of the great excellencies of that machine is the dispensing with the intermittent feed of separate sheets, and the substituting for it the continuous feed of a continuous sheet of miles in length. Within this century—in fact, within the last few years—we have had the mechanical engineer largely aiding the civil engineer. I have said "aiding," but, in one instance at least, "aiding" is far too weak a term to apply to the position of the mechanical engineer in relation to the civil engineer, for it would not be too much to say that, by the production of the locomotive engine, the mechanical engineer "created" the civil engineer, so far as that important branch of the civil engineer's business is concerned, the making of railways. In numerous other matters we have had the mechanical engineer really "aiding" the civil engineer, and especially in those appliances which have rendered practicable the performance of subaqueous works, such as our forefathers never would have dreamt of as possible. We have had him aiding the miner and the collier; and we have had him, by improved machinery, aiding the metallurgist; and upon this head it will suffice to mention the names of Neilson, Bessemer, Siemens, and Nasmyth, famous for their respective improvements in furnaces, in decarbonizing iron, and in treating the produce of the furnace, when that produce is malleable, by the steam hammer; and were it needful to prove to you the vast scope of the mechanical engineer's profession, I might do it by taking in contrast to such an improvement as that of the huge steam hammer, the delicate mechanical inventions which have been applied to the production of the finest thread, and to the use of that thread in the sewing machine. In fact, the talent of the mechanical engineer may be likened to the trunk of the elephant, which, as we all know, has been said to be competent to "root up a tree or to pick up a pin." The matters I have as yet noticed have all been connected with peaceful art, but the mechanical engineer has not confined himself to those alone, for we have had men, members of our body, past presidents of this institution—Armstrong and Whitworth—devote their powerful minds to devising weapons to enable us to defend ourselves against aggression. I will not detain you by more instances. I cease from further enumeration, not because the subject is exhausted, for that is well-nigh impossible, but because I am sure I have said enough to show you that, within the present century, the profession of mechanical engineering has originated matters of the highest value. But, if the subject of the inventions of the mechanical engineer is all but inexhaustible, that of the matters to which those inventions are applicable is absolutely so, and thus, as it is impossible to make any summary of them, I will, in sheer despair at their multitude, content myself with a bare recital of a few only of the benefits that we receive from those applications, and I will begin with mental benefits, benefits in the interchange of thought, and will only take one branch of them, that of the publication and transmission of news. Let us look how this is accomplished. The railway or the steamboat brings detailed intelligence, the essence of which, however, has been brought before by the electric telegraph. The news is put into type, but even this now is done by the aid of machinery, which arranges the separate loose types in their proper order. From these is taken a paper mould, in which castings of stereotype metal are obtained in quick succession, and in the course of a few minutes, by the aid of the planing machine and the lathe, these castings are fitted into the steam printing presses I have mentioned, and thus in less than an hour after the completion of the "composition," four or five presses may be at work, printing each its 10,000

copies an hour. No sooner is the printing done than the railway again comes into play, to distribute the papers through the country, and the telegraph also comes into play to furnish copious extracts of all the principal matter to the newspapers throughout the provinces.

To the railway, to steam navigation, and to the telegraph we owe the breaking down of the barriers called space and time, which separated nations and individuals, and to these inventions, therefore, we owe the enormous extension of commerce and of personal communication. By the aid of the mechanical engineer we obtain our fuel, for not only is he required in keeping our mines free from water, in raising the fuel to the surface, and in maintaining efficient ventilation, but to him we owe such machines as those of Mr. Firth and others, by which the most trying part of the labor of getting coal is transferred from sensitive humanity to inert iron and steel. To the mechanical engineer we owe, by the aid of the fuel so obtained, the mastery over all the intractable metals, whether as in the case of cast iron extracted from the ore in the furnace with its heated blast, and delivered in the form of "pigs;" whether converted from that form by streams of air at high pressure, as by Bessemer, or whether obtained from the ore at once in the form of steel or iron as by Siemens. Having got the metal separated from the ore, to the mechanical engineer we owe its shaping into all the desired forms, whether for rails, ships, guns, engines, or for use in our dwellings, and as regards the other materials we employ in those dwellings, the inventions of the mechanical engineer dress the stone, make the bricks, saw and plane the timber, and mould it into gracious forms. As for our clothing, from the very coarsest fabric to the most delicate lace, the hand of the mechanical engineer has been engaged on every stage of the manufacture, and the materials thus made are united to form garments by the now all but universal sewing machine, a machine which in itself is a study, and has varieties so great as to enable it to cope with the finest fabric or even with the thick and obdurate leather forming the sole of the stoutest boot; but not only do we owe to the mechanical engineer the preparation of our dwellings and of our clothing, but we owe to him the very greatest aid in the production of our food; for it is with his assistance that we till the ground, that we sow it, that we cut the crop, thrash out the grain, and convert the product into bread—in short, it is no exaggeration to say that there is no one want, one comfort, or even one luxury that is not either directly or indirectly dependent on the mechanical engineer for its production, or for the bringing of it within our reach. I have thus, in as condensed a form as possible, brought to your notice some few things that mechanical engineers have done, and some other things which result from the use of their inventions; and I think that a consideration of these must make us all proud of our profession. I know that pride is commonly held to be bad, or if not absolutely bad to be dangerous; but there is to my mind the greatest possible difference between individual pride and pride in one's profession. In the case of individuals we must all appreciate the value of modesty, and it seems to me that that modesty may, in fact must, be a result of the very pride we take in our profession; for when we reflect upon it is it not impossible for any one of us to refrain from asking himself, "What have I done to advance our profession?" The very best of us must answer, "I have done but little;" and most of us must answer, "I have done nothing;" and thus it is that, as I have said, a consideration of the dignity and importance of our profession is the means of all others to make us as individuals modest, dissatisfied with ourselves, desirous of doing better. With respect to the desire of doing better I am aware one is apt to say, "What chance have I? What is there great that is left to be done? Those men who have gone before have anticipated me; the grand substantive inventions and improvements have been made by them; they have reaped the harvest, and there is nothing but the corners of the field for me to glean." But this feeling, although natural, is one that should not be yielded to. Depend upon it, such a feeling is the suggestion of our evil genius; for although I cannot indicate to you what will be the grand inventions that will be made in the course of the next fifty years (for if I could I should go a long way towards being a great inventor myself), nevertheless we

know that within the next fifty years great inventions will be made, and we are sure that any one then looking back on the condition of things in engineering science at the present time, and comparing it with that which he will then know of, will wonder how it was that the men of this day failed to make many a grand discovery which at that time to him will be as familiar as the steamboat or the locomotive is to us. But although I am necessarily unable to predict to you what will be the great substantive inventions of the future, it is within my power to remind you of many useful directions of improvement. First, the great question of the preservation of our fuel, which, at the risk of impropriety in repeating myself, I must call the very "breath of the nostrils" of our principal machine the steam engine. About 120 millions of tons of this most valuable substance are raised to the surface in our small island every year. Such a quantity as this fairly staggers the imagination; and it seems incredible that the deposits below this minute portion of Europe can long hold out against such an annual attack, and one cannot help asking oneself, Is this quantity honestly used—is it honestly got? By that primary question "Is it honestly got?" I do not mean "honestly" in the dry legal sense—that is to say, I do not mean that any law is infringed, or that any person is doing wrongfully so as to be amenable to our Courts of Justice; but I mean is it got honestly as between man and man, as between ourselves and those who are to come after us? Do we not work coal pits with no other object than that of obtaining the utmost present profit out of them? do we not thereby leave behind the less immediately valuable coal, and, leaving it unassociated with that which is more profitable, render it all but impossible for those who come after us to get, except at too great a cost? Whereas we might by a small present sacrifice extract a great deal of that which now we think not worth obtaining. And cannot the skill of the mechanical engineer come in here to work seams which manual labor is not able to touch without the reduction of the present gain? I will say no more on the subject of "getting" coal, as I do not wish to trench upon the especial province of our brethren the North of England mining engineers, who we are happy to know are holding their meeting in this town contemporaneously with ourselves. Coal is one of "the sources of power in nature." It may be considered (as our past President, Dr. Siemens, explained last year in his lecture at Bradford) the representation of the stored-up heat of the sun; and it is part of our art to direct that source of power for the use and convenience of man, and we have so directed it by employing it in the steam engine. But have we not in consequence of the facility of its application been tempted to neglect other sources of power in nature? Have we and do we sufficiently utilize the waterfall, the tidal wave, and the force of the wind? and with respect to the employment of these forces we should remember that we are enabled to utilize water power in a way which to the engineers of the last century was unknown. They availed themselves of the waterfall—indeed, it was their chief source of motive power; but they were compelled to place their manufactories close to the falls. We, however, know that it is perfectly possible to transmit (at some cost by loss of power, it is true, but not at a prohibitory cost) power to very long distances. The transmission, so far as invention has at present gone, may be made by exhaustion of air, as practised by Hague 40 years ago, by the compression of air, by rocking rods, by swift running wire ropes, and by the employment of water under pressure as practised by Sir William Armstrong. But do we resort to all those facilities for transmitting power from a distance? Do we resort to any large extent to sources of power in nature other than coal? Is it not the fact that mechanical invention has gone back in these matters rather than forward? and do we utilize that primary source of power, the heat of the sun, the current heat from year to year, by making the most of barren hillsides, as, it seems to me, we might do by planting quick-growing trees, which, fostered and matured by the sun, would yield large quantities of wood to be used as fuel for domestic purposes? Are we estimating at their full value the deposits of peat? and are we not tempted to pass by this large store of fuel because its use is attended with difficulties? In those cases where coal must be used for power, has it not to be

admitted that in far too many instances it is recklessly, wickedly employed; that the engines are, in their design and construction, disgraceful; and that a consumption obtains equal to four, five, or even ten times that which would suffice with proper engineering care? In the same way when we employ coal for heating purposes only, such purposes as metallurgical operations demand, is it not in too many instances used in the grossest manner? How much of the fuel goes up the chimneys of our furnaces unconsumed in the form of visible carbon, or in the worse, because less detectable, form of invisible carbonic oxide? How much of the heat of the coal escapes uselessly into the air in jets of flame, which in the night time throw their light around for miles? It cannot be doubted that we have been and still are, although I believe and trust we are improving, most cruelly wasteful, and, as I have said, wickedly wasteful. It pains me when I hear a man talk of "only a bit of coal;" he cannot think of what he is saying. "Only a bit of coal!" Only a bit of that which might have helped to gladden some man's fireside. "Only a bit of coal!" Only a bit of that which if not wasted but properly used might have helped and might have succeeded in saving some noble vessel with all its brave crew from perishing on a lee shore. "Only a bit of coal!" Only that which might have assisted in wringing the bright metal from the sullen dross with which it had been associated for countless ages. "Only a bit of coal!" Only that which has been got at the peril of men's lives, and not at the mere peril but at the actual cost of men's lives, for ten men die violent deaths for every million of tons raised. "Only a bit of coal!" Only part of the store which the Almighty had buried in the recesses of the earth to be treasured up there for the use of generation after generation. It really is grievous to hear men talk slightingly of "only a bit of coal;" and I think it becomes us mechanical engineers, by precept, practice, and example, to do all that lies in our power to cause persons to respect and to understand the value of that which they have but too long lightly treated and grossly abused. I feel I owe you apology, or at least explanation, for the remarks which I have made upon the saving of coal, because remarks of this character have of late years been made by others than myself, and I personally have made them before another scientific meeting; but the truth is that my mind is so forcibly impressed with the importance of the question that I hardly know how to refrain from alluding to it, especially when I have the opportunity, as I have now, of addressing a body of gentlemen who of all others are those who can do most towards curing the evils of which I have complained; and further, in excuse of my having to some extent repeated myself on this subject, I will ask you to remember that however important a reform may be, it is not brought about by a single statement, although the facts contained in that statement may be absolutely incontrovertible, but that improvement and reform need for their carrying out repetition and reiteration of the circumstances which render such reforms necessary. I have occupied so much time in this question of the improvements which might be effected in relation to the getting and use of coal, that I will merely, in a few words, allude to some other directions of improvement within the scope of our profession. One of these is the substitution of mechanical force for that of manual labor in all cases where the labor is that which though rendered by man does not demand the exercise of human intelligence—mere brute labor—as when men are employed to raise weights. We are, however, so used to this that we are not shocked at the sight of a man turning an ordinary crane; but when, as in years gone by, one might have seen in the London Docks, and when, as I have recently seen on the Continent, men are performing the same work by working inside a tread-wheel and causing it to turn, we involuntarily think of the turnspit, and are compelled to admit that this is mere brutal labor—labor indeed to which we put our convicts as a punishment; and one feels that a man like Sir William Armstrong, who by his invention transmits the force of a central engine in some large dock, or on a quay side, to all the cranes and hoists within its area, is a benefactor to the human race, because, hard as it may be at the time of the change, he has by his invention rendered it impossible for a man to earn his bread by the exertion of muscular strength with-

out the exercise of intelligence, and thereby he is really doing his part in the progress of humanity. There is another class of labor, which, although it demands high skill, and therefore does not come within the category of brutal labor, but is far from it, yet on account of its fatiguing and exhausting nature one would wish to see superseded. I allude to such labor as that of the hewer of coal, and to such labor as that of the puddler. In these two instances, however, we are happy to know that we are far on the track of substituting mechanical appliances for the arm of the workman. Then there are open to our members improvements in the comfort and in the safety of our travelling by land or by sea. I trust I am not too sanguine when I say that I hope for greater speed in both those modes of journeying, for greater comfort, even in the mastery of sea-sickness, and for greater safety by better signals and by improved modes of communication between those on the train and those in the station or signal houses, and by better means of rapidly and safely arresting the speeds of trains. Again, I think one may look for more satisfactory modes of uniting materials. In the constructive arts, there is no doubt that the uniting of the materials is as supremely an important part as in the construction of a sentence is the verb; in fact, it is a mere truism to say that without the means of uniting, construction is impossible, unless construction were confined to that of those former ages into which I have said I would not travel, where it meant little more than placing one stone upon another. It is, I must say, a disgrace to mechanical engineering that we cannot unite such materials as iron or steel without the barbarous expedient of cutting away a large percentage of their strength by making holes to admit of the insertion of bolts and rivets, and we ought to be able to devise means of union by welding, which should almost entirely supersede our present very primitive mode of procedure. The foregoing are all matters for ourselves alone, but there are others where either alone or in conjunction with the chemist there is obvious room for improvement; such are the making use of the so-called, and in most cases most improperly so-called, "waste products" of our various manufactures, the getting rid of gases and fumes deleterious to health, the obtaining of purer water in our dwellings, and the saving of metal in metallurgical operations, for too surely do we now needlessly waste, in many of those operations, the very metal which should be their product. I will not continue further these suggestions, but will only repeat that, in the absence even of great substantive discoveries, such improvement affords wide scope for the mechanical engineer, and therefore the prospect of those who are to follow us is by no means a gloomy one, and it must be remembered that those men will come to the subject with advantages which very few of their predecessors possessed. Most of us had to rely on our innate love of the profession and our mother wit for all that we have done. Technical education in our day was a thing unknown, and scientific education fell to the lot of but few; but those who succeed us have, or if they have not it is their own fault, the advantages which were denied to us of scientific training, and therefore, as I have said, they not only have a wide field before them, but there is good reason to believe that by their training they have every facility for cultivating it. While on this subject, I cannot refrain from saying that the success of the men of the past generation, in the absence of special training, was, I believe, in a large measure due to this—that they became engineers literally because they could not help it; that the taste for it was born with them, and that their very natures compelled them to follow that taste, and when men enter the profession from such causes as these it is not surprising that they succeed, even in the absence of extraneous aid. But now-a-days it is too commonly the fact, I am afraid, that a man becomes a mechanical engineer as he might become a wine merchant or a stockbroker, because his father wants him to earn his livelihood in some way, or because he has got capital at command, and not because he has the real love of the profession in him. Such a man may succeed, but if he do he will do it as a mere manufacturer, about whom and about the subdivision of our profession I now wish, in conclusion, to say a few words, as they are both subjects which may prove sources of danger to the advancement of that profession. Forty

years ago the business of a mechanical engineer was general. The man who made a marine engine, made a locomotive, made mill work, and made land engines, but within the last few years the business of the mechanical engineer has divided itself into distinct branches, so that the locomotive builder is little more than a locomotive builder, or the marine engineer than a marine engineer. I presume such division is the almost inevitable result of the growth of an industry, and so long as the productions of that industry are not intimately connected with science, separation is probably a thing to be desired as cheapening the article produced; but in the business of the mechanical engineer, closely allied as that is to science, the separation of his industry into branches appears to me to be dangerous. It narrows his opportunities of gaining knowledge in his profession, and he is in danger of becoming the mere manufacturer. But the division into branches to which I have alluded must, I am afraid, continue. It is most desirable, however, that those who, by their commercial practice, are devoting themselves to one section alone of the mechanical engineer's business should, as a matter of duty, keep themselves thoroughly acquainted with the state of all the other sections of our profession, and with the improvements that are being made in those sections; and I know of no better means of so doing than by their lending their heartiest co-operation to the advancement of our institution, by communicating to it all that is useful that comes within their knowledge, and by assiduous attendance for the purpose of testing, by discussion, the value of that which is brought before the Institution, and of adding by their remarks to the information imparted in the papers; but to those of our brethren who are so absorbed in their business as manufacturers that they care not to devote time to advancement of the general scientific position of the profession, I will still say that they may uphold its usefulness, and even its dignity, by the excellence of the products of their manufacture, and let us trust that competition, however keen it may be, and whether between the natives of these islands, or whether between them and the foreign manufacturers, may never drive our members to seek commercial success at the cost of the excellence of their work, but that competition may have the opposite effect, and may make them feel that in a high reputation lies the best hope of excelling and of gain, and thus competition itself may be the means of causing them to discharge their duty to the profession of which they are members. I fear that in this address there are to be found occasionally the tones of censure mingled with those of exhortation, but if this be so, it has arisen from my desire to bring before you that which I believe to be the truth. It is well that some one should bring the truth before us from time to time, and that in this instance it has been done by me is the result of your own act, because it is you who have selected me as President of the Institution. This address has grown to a greater length than I had intended, such a length, indeed, as to make me feel that I have incurred the risk of wearying you and of making you impatient by keeping you from the regular business of the meeting; but I shall not have incurred that risk in vain, if I have succeeded in that which I set myself to do at the outset—namely, the withdrawal of your minds for a short time from individual interests and pursuits, to the consideration of the broad features and aims of our noble profession; and if in any way I have stirred you up to resolve to do all in your power to advance that profession to which we are all, I trust, proud to belong—the profession of the mechanical engineer.

NEW WHITE ALLOYS.—White metallic compounds are frequently patented, and seem for some reason to be more in demand than those of any other color.

The following, invented by an English metallurgist, Mr. Parkes, of Gravelly Hill, is the latest. It is a silver-like alloy which can be rolled and worked when red-hot from copper, manganese, zinc, and sometimes nickel. A silver-like alloy which will also work at a red heat is also produced from nickel, copper, and zinc. When the silver-like alloy is not required to work at a red heat, it may be produced from copper, manganese, iron, and zinc. A solder for these compounds is produced from copper, manganese, and silver.—*Mining Journal.*

THE CONDITION IN WHICH SILICON EXISTS IN PIG IRON.

By MR. E. HANDFIELD MORTON.

From "Journal of Iron and Steel Institute."

I was induced to make a few experiments upon the subject of this paper, by noticing that silica was obtained in the insoluble residue when pig iron containing a large quantity of silicon was dissolved by dilute sulphuric acid *in vacuo* instead of silicon, which might have been expected as the result of the decomposition of the pig iron under these conditions.

This fact appeared to clearly point out that the theory of silicon being intimately mixed with pig iron was untenable, at least as regards this particular pig, which was a No. 1 Bessemer iron, containing 4.612 per cent. of silicon, and was, therefore, not at all unlikely to contain silicon in admixture, if that element ever occurred in pig iron in such a condition.

As far as I am aware, no experiments have been made with the object of proving that silicon exists in a state of combination in pig iron, although I believe it is the generally received opinion that such is the case. I therefore made a considerable number of experiments with the view of ascertaining how far this conclusion was correct.

Weighed quantities of the Bessemer pig iron were placed in sealed tubes with Nordhausen sulphuric acid, in atmospheres of carbon dioxide and hydrogen, and also *in vacuo;* the tubes were then heated in an air bath by two Bunsen burners for twenty-four hours, but in every case the silicon contained in the pig iron had been converted into silica, and a small quantity of sulphur dioxide formed in the tube, which occasioned sufficient pressure to blow the top off the tube when cracked with a file. On examining the insoluble residue from these experiments under the microscope, perfectly transparent crystals of silica were observed interspersed with opaque pieces of the same substance. When these insoluble residues were treated with hydrofluoric acid, complete solution was effected.

The next attempt to isolate the silicon in this pig iron was made by heating weighed quantities of the iron with an excess of pure iodine in sealed tubes, all air being first displaced by carbon dioxide, the same heating arrangement being used as in the sulphuric acid experiments. At the end of twenty-four hours, all iodine vapor having disappeared, one of the tubes was opened and the contents analyzed, with the following results:

Iodine	76.432 per cent.
Iron	20.013 "
Silica	1.709 "
Carbon	0.759 "
	98.913 per cent.

Directly the tube was cracked, the pressure of gas blew the top off. The contents consisted of dull red lumps, the whole of the iron having been converted into the ferrous iodide, as the above figures correspond to the formula FeI_2. There can be little doubt but that the silica which was formed in this experiment was due to a slight decomposition of the carbon dioxide with which the tube was filled; the greatest part of the silicon having been converted, in all probability, into an iodine compound. For, although iodine vapor is without action upon silicon under ordinary conditions, it is highly probably that when silicon in the nascent state is presented to iodine vapor, a compound of iodine and silicon may be formed. These results were confirmed by several other similar experiments. This pig iron was also carefully tested for graphitoidal silicon, by treating the iron with hydrofluoric acid; the insoluble residue was filtered off and ignited to get rid of carbon, when a mere trace of a dark powder remained, which proved to be iron.

From these results, it may fairly be concluded that the silicon contained in pig iron does not exist in a state of mechanical mixture, but exists combined with a portion of the iron as a silicide of iron, in the same manner that carbon exists as a carbide of iron, only differing from carbon in so far that it does not exist in a graphitoidal form in pig iron. If the pig iron used had contained any uncombined silicon, it would have been

found in the insoluble residue from the experiments with Nordhausen sulphuric acid and hydrofluoric acid, as it is insoluble in even the latter acid, after having been strongly heated, and as any uncombined silicon must have been heated intensely in the blast furnace, there can be little doubt that as a rule, pig iron does not contain any uncombined silicon.

I then made the following experiments in order to ascertain whether or not the hypothesis of the combination of the silicon with the iron was correct: 0.1694 grm. of the Bessemer pig iron was placed in a platinum boat, which was then introduced into a porcelain tube. A current of carbon dioxide was passed through the tube to displace the air, after which pure dry hydrogen was passed through until all the carbon dioxide had been driven out. The portion of the tube which contained the boat was then heated for five hours to a very bright red heat in a Fletcher's gas furnace, the current of hydrogen being maintained until the tube was cold. The boat was then withdrawn and weighed, when it was found that a loss in weight of 0.004 grm. had taken place. The gas, as it left the apparatus, was passed through a wash bottle containing a weak solution of pure caustic potash (prepared from alcohol); at the end of the experiment, this solution was made acid, and with pure hydrochloric acid evaporated to dryness and ignited, when an insoluble residue of silica was obtained, which gave 0.344 per cent. of silicon on estimation. The iron in the boat (which after its withdrawal from the tube showed no sign of oxidation) was analyzed with the following results:

Iron	92.018	per cent.
Silicon	4.130	"
Graph. Carbon	1.622	"

For comparison with the above analysis, is subjoined that of the pig iron used:

Iron (by difference)	92.375	per cent.
Graph. Carbon	2.800	"
Silicon	4.612	"
Phosphorus	0.110	"
Sulphur	0.103	"
	100.000	

This shows that there is a loss of silicon to the amount of 0.482 per cent.

The above experiment was repeated several times with almost identical results. It will be observed that the amount of silicon found in the caustic potash solution very nearly corresponds with the loss of silicon sustained by the iron operated upon. Thus, 4.130 per cent. + 0.344 per cent. = 4.474 per cent. silicon, instead of 4.612 per cent.; the difference being 0.138 per cent.

In the event of the silicon being in combination with the iron, I calculated in the above experiment upon the reducing power of hydrogen being able to decompose the silicide of iron, with the formation of silicuretted hydrogen, which would be decomposed by the caustic potash solution; and this appears to have taken place. Possibly the temperature of molten iron is required to effect the decomposition of the whole of the silicide of iron, or else the attraction of iron for silicon is so strong as to defy, in a great measure, the reducing power of hydrogen. This last hypothesis is by no means improbable, when the high temperature of molten iron is taken into account, for the fact is generally admitted that chemical affinities are frequently reversed in the presence of an intense heat.

A sample of white pig iron containing a large quantity of silicon having been given to me, I thought it might be interesting to ascertain whether hydrogen had the same effect upon the silicon contained in the white iron as it had upon that found in the Bessemer iron used in the preceding experiments. 0.1420 grms. of the white iron was heated in the same apparatus, and under the same conditions as existed in the previous tests, for six hours at nearly a white heat. When cold, the iron was analyzed, as was also the caustic potash solution, with the following results:

Iron	89.201	per cent.
Graph. Carbon	1.060	"
Silicon	4.287	"

Caustic potash solution: silicon=0.494 per cent.

The composition of the white iron used is shown by the annexed analysis:

Iron	90.000	per cent.
Grap. carbon	2.975	"
Silicon	4.704	"
Undetermined	2.321	"
	100.000	per cent.

The amount of silicon found in the caustic potash solution is 0.077 per cent.

more than is required to account for the loss of silicon sustained by the irons used, which amount may be said to be within the limits of error of experiment.

The following table shows the amounts of loss of silicon sustained by the iron used in these experiments, and also the quantities of silicon found in the potash solutions:

	Loss of Silicon.	Silicon found in Potash solution.
Bessemer pig iron=	0.482 per cent.	0.344 per cent.
White " =	0.417 "	0.494 "

On comparing the results obtained from the two kinds of iron used, it is evident that the effect of hydrogen upon the silicide of iron is identically the same in both cases, and this has led me to believe that the amount of silicon lost by the iron in each case is due to the silicide of iron containing an atom of non-saturated silicon, or in other words, that the silicide of iron was super-saturated, and consequently the non-saturated atom of silicon united with the hydrogen, leaving a lower silicide of iron undecomposed. It is my intention to endeavor to prepare and isolate definite silicides of iron. If the experiments should prove successful, the chemical composition of the silicides may throw some light upon the forms of combination of silicon in the various kinds of pig iron now in use.

In conclusion, it may be fairly considered from these experiments that silicon in pig iron is not contained in a state of mechanical mixture (except perhaps under peculiar circumstances), but as a chemical compound of iron and silicon, dissolved, so to speak, in the pig.

IRON PIERS.

From "The Engineer."

Of all braced structures, an iron pier, built according to the principles of modern engineering, depends more than any other for its security and durability upon the manner in which the bracing of the component parts is designed and executed. As the type for an illustration, we may select a pier consisting of three principal parts, viz., iron piles, driven or screwed; iron superstructure, solid or open; and timber platform or decking. If we restrict our selection still further, and make the foundations cast iron hollow screw piles, the superstructure lattice girders, and the decking, narrow planks close jointed, we shall probably arrive at the description of pier possessing the minimum amount of inherent rigidity, demanding at the same time the maximum amount of extraneous stiffening and bracing, and yet capable of being erected with all due regard to both scientific designing and permanent economy. A pier built in the manner described may fill in various ways; thus the holding powers of the piles may be sufficient; they may be bodily uprooted, and the whole superincumbent structure come to the ground, or fall into the water, as the case may be, and the same result might also be produced by the scouring out of the ground at and around the piles. At home this disturbing cause is not likely to occur, but it is by no means an uncommon event in India and other foreign countries, where rivers have been known to scour out their beds to a depth of nearly 40 ft. in a single night. In ordinary cases, the precautions used against the uprooting of the piles are a screw blade of sufficient diameter, the proper pitch of screw, and a penetration into the bearing stratum to the extent required. The first two of these conditions are generally complied with, but the third, from motives of false economy, is very frequently violated. Directors of companies are very prone to cut down estimates so closely, that an engineer will sometimes cheapen a design in the simplest manner possible. This, in the case of an iron pier, is readily effected by diminishing the depth to which the piles are to be screwed, without in the least degree affecting the rest of the structure. Nothing can be more injudicious or short-sighted. An engineer had better fine down his material, use second-rate timber, and employ any alternative to bring, if possible, the cost of the structure within the prescribed limits, than diminish by a single inch the holding power required for the piles. Dam-

age done to the superstructure can be repaired with comparative facility, but if a few piles happen to give way, the whole structure is in jeopardy.

While all the component parts of an iron pier should present as little surface as possible to the action of the waves, yet a certain amount of strength, and consequently of material, is indispensable. But it is with regard to the decking that especial precautions must be taken to avoid the force of the sea. Obviously, if the upward pressure of the water were once brought to bear upon the under surface of the deck, nothing could prevent it being lifted off the girders, or as it is commonly called, blown up. We do not suppose that any engineer would arrange the levels of a pier in such a manner that this catastrophe would happen under ordinary or even extraordinary tides. But the question of storms must be taken in consideration, and in connection therewith another point must be noticed. In order to blow up the deck it is not necessary that the waves should actually come into contact with its under surface, especially if the breadth of the pier be upwards of 40 ft. The rising of the sea in a heavy storm, together with the violence of the wind, may so compress the air in the confined space between the surface of the water and the under-side of the deck, as to produce precisely the same result as if the waves themselves rose to the deck level. It might be imagined that a remedy against this contingency might be easily provided by the simple expedient of laying the deck boards with the space of about an inch or thereabouts between them. Under certain circumstances there can be no doubt that this precaution would prove advantageous, but it is quite a mistake to suppose that it would prevent the blowing up of the deck in the event of the waves acting during a severe storm in the manner already described. The suddenness of the shock and the velocity of its action would easily start or break the planks. Besides, small spaces between deck boards after a time usually become more or less choked up with dirt and grit, so that even the partial advantage derived from their adoption is considerably diminished. We are not to be understood as condemning the practice of employing open decking. On the contrary, in certain cases it should always be adopted. When a pier is erected solely for the purpose of trade and commerce, and for the loading and unloading of goods, it should always be used. What we intend to imply is, that its advantages as a means of increasing the security of the structure are frequently much overrated; in consequence other necessary precautions are neglected or treated as of secondary importance. The decks of piers intended to serve as resorts for fashionable promenade, such as those at Brighton, Hastings, and elsewhere, are best closely laid and well caulked. Apart from other considerations, open decking should be employed whenever practicable for reasons of economy. Not merely are fewer squares of planking required, but the expense of caulking is avoided, which is a serious item in the total cost.

The proper method for obviating the dangerous tendency of the waves to blow up the deck of a pier is to place it at sufficient height above high-water mark. Here again, from motives of false economy, an error is likely to be made. An increase in the height of a pier necessitates a corresponding increase in the cost of the whole of the sub-structure, and in some instances in some portions of the superstructure as well. The pier at Blackpool, in Lancashire, is an example in which this mistake was originally committed. During its erection—which, owing to the unfavorable weather, made at first rather slow progress—the storms which occurred in the autumnal months indicated that the structure was being placed at too low a level. Fortunately there was time to profit by the warning, and the whole pier was raised three feet higher than had been originally contemplated. While having due regard to the height of the pier with reference to the protection of the deck from the action of storms, that dimension must not be increased beyond what is required, not only for the reason already given, but because the difficulty of access is thereby enhanced. So far as a promenade pier is concerned, this last consideration is perhaps not of much importance; but it becomes one of the points demanding the greatest care and attention when the structure is erected to accommodate the trade of a place. There is always a natural desire on the part of the proprietors of piers, wharves, and landing-places, to lessen the lift as much

as possible, and it is therefore no wonder that under the circumstances the level of the surface is sometimes too low. The cause of the inundation which in March last laid under water a large portion of the districts of South Lambeth, on the Surrey banks of the Thames, was the fact that the level of the top of the walls of the various wharves was not sufficiently high. The extraordinary tide which recurred in the river at that time reached in some cases to a height of more than a foot over the walls.

The weakest portions of a long pier—that is, one which is not less than a quarter of a mile in length—are, in a constructive sense, the shore end, or commencement, the central part, and the termination or head. We may consequently divide a pier into three parts, each of which ought to be able to stand alone without the assistance of the intermediate connecting lengths. In other words, if we suppose these intermediate lengths to be carried away by a storm, these three nuclei, or *points d'appui*, ought to remain intact. On the other hand, if the latter are destroyed, the intermediate parts will go likewise, and are not expected to do otherwise. Viewing the subject in another light, the actual erection of the pier may be carried on in one of two ways. The work may advance, as is usually the case, gradually and progressively from the shore; or the shore ends, central part and head may be first constructed, and the remainder subsequently added. Whichever course may be adopted—and supposing the theoretical assumptions respecting the stability of the three points to prove true in practice—there would still remain the chance of the intermediate portions being carried away before they formed part and parcel of the whole continuous structure. The absence of this continuity between what are assumed to be the self-supporting parts of the pier, constitutes the danger and risk incurred in its erection. It is far more likely to suffer from the effects of stormy weather while in a disconnected and incomplete condition than when in a finished state. The whole structure is so braced that it cannot sway laterally, and any tendency of this kind in a longitudinal direction must be counteracted by the pier being immovably tied at the shore end, at the central part, and at the head, or at any rate at the first and third of these points. Too much care and attention cannot be bestowed upon the bracing of the head of a pier. As a rule, the heads of piers are too small, and do not afford that strength and stability which they not only require themselves, but which are also necessary to the security of the rest of the structure.

REPORTS OF ENGINEERING SOCIETIES.

INSTITUTION OF CIVIL ENGINEERS.—At the sixth ordinary meeting of the session 1874-'75, held on Tuesday evening, the 15th of December, Mr. Thos. E. Harrison, President, in the chair, the first paper read was on "The New South Breakwater at Aberdeen," by Mr. William Dyce Cay, M. Inst. C. E.

The New South Breakwater formed part of the scheme of improvements now being carried out by the Aberdeen Harbor Commissioners under the Act of 1868, and was completed in the autumn of 1873. After describing the object of the breakwater, and the design upon which it was originally commenced, the author observed that in carrying out the work, various methods of building with concrete in a liquid condition deposited *in situ* were tried. The results proving satisfactory, the original design was to some extent departed from, and the portion of the work in deep water was executed in the following manner: The foundation, after the loose material had been removed, was laid with large bags containing liquid concrete; the work was then carried up with concrete blocks, of from 10 tons to 24 tons each, to 1 foot above low water of ordinary neap tides, from which level to the roadway, a height of 18 feet, it consisted entirely of liquid concrete deposited *in situ*. The toe of the breakwater was protected by an apron of bags, each containing about 100 tons of liquid concrete. Near the shore the foundation rested on rock, then, for a space of 100 feet, on boulders and gravel, and the outer portion was clay mixed with gravel and covered with large stones. The bags containing the liquid concrete were deposited in the foundations from iron skips, the bottom of which opened on hinges by the action of a trigger, and so discharged the bags. The sea staging consisted of a solid timber framework supported on Oregon pine masts, which rested on cast-iron shoes, each weighing 11½ cwt., and having a socket on the upper side to receive the foot of a mast. The sole of each shoe was a flat octagonal plate 3 feet 8 inches across. The top of each mast had a cast-iron cap, with a socket 4 feet deep, the upper side being a flat, triangular table, measuring 6 feet 10½ inches by 6 feet 2 inches, to which the timber superstructure was fitted. The weight of each cap was 32 cwt. The superstructure of timber girders was composed of large logs keyed and bolted together, no trusses being used, and the whole was braced with ties and struts, and, for additional security, tied to anchors. It was stated that a length of 108 lineal feet of the staging had been erected in four weeks.

The system of building with liquid concrete deposited *in situ* above low-water level was then

described. With respect to progress and cost, it appeared that from the time the machinery was fairly at work, about 300 lineal feet had been completed per annum; and that, taking into account the value of the plan now being used on another of the Aberdeen Harbor works, the cost had not exceeded the estimate. The total length of the breakwater was 1,050 feet, and on this £76,443 had been expended. In conclusion, the opinion was expressed that concrete blocks of the ordinary size of from 10 tons to 20 tons each were not suitable for building a solid breakwater on sand or other soft material, and it was recommended that the parts of such a work below low water should be in blocks of from 100 tons to 200 tons weight each, and that some of these blocks might with economy and advantage be deposited in a liquid state in bags.

The second paper read was on "The Extension of the South Jetty at Kustendjie, Turkey," by Mr. George Lenton Roff. This jetty, previous to its extension, was 450 feet long, and was protected against gales by a mole of pierre perdue and concrete blocks. The design for the extension was governed by the following points: It was to be regarded as a breakwater, to be so constructed as to avoid the necessity of lengthening the mole, and the existing traffic accommodation and loading-berths were to be interfered with as little as possible. These considerations made large concrete blocks necessary, and restricted the space available for operations to the last 50 yards of the existing jetty. The design adopted was that of concrete blocks, weighing about 30 tons each, resting upon pierre perdue. The stability of the blocks was tested by leaving five tiers untopped from September, 1872, to July, 1873, at the then extreme end of the work. They were exposed to very heavy seas during the winter; but none of them were disturbed, except by ordinary settlement. The total length of the pier was 253 feet 6 inches; and the total cost, including that of the plant, had been about £13,000. The blocks in every case settled vertically, without disturbing the line of direction, the only effect of settlement being to open the joints of the concrete cap; and the slight openings at these points could easily be filled up with cement. The original design was by Mr. Liddell. The work had been executed by the author for the Danube and Black Sea Railway and Kustendjie Harbor Company (limited).

IRON AND STEEL NOTES.

THE "SHEFFIELD TELEGRAPH" states that Mr. John Heaton, C. E., at present resident in Sheffield, is coming to the front again with a system of making iron and steel which, if carried to a successful issue, promises to mark a new phase in the history of these industries. This gentleman has studied the manufacture of iron and steel from a chemical point of view, and has succeeded in producing high-class products in a shorter time, at less expense, and with greater ease, than any producer who has yet preceded him; and the results of his discoveries must have an enormous influence on the trades with which he is connected. We believe that Mr. Heaton is the owner of three several patents, and that in connection with a company he, until the year 1869, successfully carried on the manufacture of iron and steel at Langley Mill. A litigation arose which has proved a long one, but Mr. Heaton is at last in possession of his patents, which he intends to work as soon as possible.

ECONOMY OF FUEL IN FURNACES.—M. Foucault, in a report to the Industrial Society of Rheims, combats the idea that the smokelessness of a fire can effect a notable saving in the amount of fuel burnt. He alleges also, on the other hand, that a considerable loss of economy is produced by smoke-consuming apparatus. He brings, in support of his opinion, the long series of observations made by the Industrial Society of Mulhouse, which have proved that, with the ordinary boiler furnaces, it is only necessary to consume from 125 to 150 cubic feet of air for each pound of coal, while furnaces, for the most part, pass twice that quantity. If the draught be reduced in quantity, much smoke is evolved, but the products of combustion, circulating more slowly, part with their heat more readily to the boiler flues. It is further proved that the best means of reducing the loss of heat by the chimney is the use of feed heaters in the flue, so as finally to reduce to 200° the products of combustion, which are often discharged as hot as 400°. Feed-water heaters well set, will produce an economy of from 11 to 20 per cent., with a reduced draught. The conclusion is that furnaces with large area and suitable feed-heaters are the most economical in all respects. But in order to obtain the best results much care is needed in stoking. A little at a time and often should the coal be spread over the front of the fire, and the bright coal pushed back to the bridge. At the same time, the least possible quantity of cold air should be admitted.

NEW METHOD OF REROLLING RAILS.—The Pittsburgh "Manufacturer" says: "A new method of rerolling rails has been invented by J. P. Edwards of Cleveland, and patented by Messrs. Edwards and Rogers. The old rails of 60 pounds are cut in lengths of 15 feet, and reduced to 25 and 30-pound rails by passing through a set of rolls turned for that particular purpose. The rail is finished in five passes. The advantage of this invention is obvious and has been long sought after. The North Chicago Rolling Mill of Chicago are introducing the patent into their mill. The same party also patented a pair of billet rolls to reduce steel rails to billets without lap or crease; also to roll splice bars from crop ends of rails."

CALCINATION OF NATIVE OXIDES OF IRON.—In Sweden, and most other countries where iron is smelted with charcoal, the universal practice, from the most ancient times, has been to subject the nearly pure native magnetic and specular oxides of iron to a preliminary calcination before charging them into the blast furnace. The reasons for so doing, if we except the statement that in practice it has been found better, have been variously given, and metallurgists generally are not agreed as to the true explanation as to why this preliminary calcination should be necessary. The results of an experimental inquiry into this subject have recently been published by M. H. Tholander, in the first and second numbers of Jern Kontorets Annaler for this year, which, however, have reached us too late to prepare an abstract for this present report.—*Journal of Iron and Steel Institute.*

FLUXES FOR STEEL.—In his work on the treatment of phosphoric irons, both wrought and cast, Lancauchez gives the composition of the fluxes made use of by MM. Verdie and Micolon, for the manufacture of steel by means of iron and steel scrap. The following are two recipes employed by these gentlemen:

No. 1.	Kilogrammes.		
Peroxide of manganese	0.750	to	2.000
Tungstate of iron	0.200	"	0.700
Borax	0.300	"	0.900
Carbonate of soda	1.000	"	2.000
Quick lime	0.000	"	0.500
Pulverized charcoal	0.150	"	0.600
Total for 100 kilogrammes (nearly ½ cwt.) of cast steel	2.400	to	6.700

No. 2.	Kilogrammes.		
Peroxide of manganese	0.500	to	2.300
Tungstate of iron	0.150	"	0.750
Borax	0.400	"	1.090
Carbonate of soda	1.500	"	3.000
Sal ammoniac	0.150	"	0.300
Pulverized charcoal	0.100	"	0.500
Total for 100 kilogrammes (nearly ½ cwt.) of cast steel	2.800	to	7.850

These substances were well ground together, then calcined in old worn-out crucibles placed in the furnaces at a low heat, so that, during the night, perhaps for twelve or fourteen hours, the mixture was exposed to a temperature of from 1,200° C. (2,292° Fahr.) at the beginning, to 500° C. (932° Fahr.) at the end.

It is easy to see that, in this calcination, manganate of soda and basic borate were produced, and that the sal ammoniac was completely decomposed under the form of chlorine and chloride of iron evolved by the tungstate of iron; then, the water in combination with the borax and the carbonate of soda, being partially decomposed at temperatures of 600° C. (1,112° Fahr.) was obliged to give up some of its oxygen to the peroxide in order to facilitate the formation of the manganates of soda and of lime.

It will be remarked that in this chemical process there is no trace of silicium in the products mentioned, which, with respect to the acid, had played the part of the most energetic bases, thus accounting for the fact that their use was only possible in plumbago crucibles; now, as it was by chance that MM. Verdie and Micolon were unable to procure in Paris other crucibles than those of plumbago, which came from England, it is due to this chance, says M. Lancauchez, that a process has now succeeded, which before had always failed.

The recipes of MM. Verdie and Micolon approach very nearly to that of M. E. Gallet:

	Kilogrammes.		
Alumina	0.500	to	1.000
Clay	0.120	"	0.200
Pulverized charcoal	0.500	"	0.500
Carbonate of lime	0.380	"	0.420
Carbonate of potash	0.180	"	0.300
Carbonate of soda	0.020	"	0.020
Caustic potash	0.500	"	1.000
Oxide of manganese	0.040	"	0.040
Resin	0.040	"	0.050
Muriate of soda	0.010	"	0.010
Sal ammoniac	0.500	"	1.000
Borax	0.500	"	1.000
Water	40 per cent. of the weight.		

This mixture must be made with care. The quantity to be used per 100 kilogrammes (nearly 2 cwt.) of steel, varies from 3 to 7 kilogrammes (about 6 lb. to 15 lb.)—*Iron.*

DIRECT MANUFACTURE OF STEEL.—It may have been thought by some that, with the Bessemer steel process, we had seen the last startling innovation in the commercial manufacture of steel; but, according to the latest news from Vienna, we are, perhaps, on the threshold of a further startling revolution in the metallurgical processes for the production of commercial steel. It is that of "direct" production of pure steel from the ore. For many years metallurgical engineers have been endeavoring to substitute the treatment of minerals in cupola or blast-furnaces, by their reduction in reverberatory furnaces. All efforts hitherto attempted in Europe or in the United States have failed to bear any considerable fruit. It is now thought that this problem has at last been solved.

The first run of steel took place on the 27th of September last, at the ironworks of Verrières (Vienna) belonging to M. Robert de Beauchamp, produced by direct treatment of the ores in a reverberatory gas furnace on the Ponsard system. The inventor himself conducted the operation with the assistance of M. Peripé, Director of the Société Genérale de Métallurgie at Paris. The apparatus was essentially composed of a gazogene, which transformed the "combustible" into the gaseous state; a large chamber of many compartments, in which the operations were conducted, and an apparatus in brick called the "Regenerator," which absorbed the waste heat of the furnace, and gave it back in the form of hot air. The compartments of the working chamber served successively for the reduction of the ore, for the reactions that had to be accomplished, and finally for the fusion of all the materials, so that the separation by the difference of densities should become possible.

These different phases of the operation required very different temperatures, and this is what the form of furnace is eminently suited to supply. At the charging doors furthest from the combustion chamber the furnace is only of a red heat, while nearer the combustion chamber the heat is so intense that one cannot look into the furnace without being dazzled. This temperature is estimated at 2,000° C.

The success has been greater than was hoped for. The result obtained at Verrières showed clearly the possibility of producing steel direct from the ore, without passing through all the processes hitherto used. If the actual practical results—and we can see no insuperable impracticability in the process—should at all approximate to the above startling facts, we cannot but think that our ironmasters have been outdone on their own ground, and that this is the foreshadowing of a further great revolution in the iron trade.—*Iron.*

ELECTRO-DEPOSITION OF IRON.—An interesting paper was read by M. Volger before the Frankfort Society of the Physical Sciences last autumn, which we have not seen properly noticed in England, and from which we extract the following notes relative to the treatment of iron:

Forty years ago M. Peligot succeeded in reducing chloride of iron by means of hydrogen gas, obtaining regulus of iron in octahedric crystals; and he also succeeded in preparing small malleable plates.

In 1846, M. Boettger succeeded in decomposing chloride of iron by galvanism, but he soon found that a mixture of ammoniacal sulphate and chloride of iron was more advantageous for the purpose, and he prepared this mixture very simply by dissolving together two parts by weight of sulphate of iron and one part of sal ammoniac. He employed a piece of iron plate at the positive pole, and at the other a piece of metallic iron scraped bright. He thus produced beautiful iron coins, the metal of which was extremely hard and steel-like, but so brittle that the medals often broke in pieces when taken from the moulds. It was therefore thought impossible to make any industrial use of this method.

In 1859, however, M. Jacquin published his method of depositing an excessively thin coating of iron on engraved copper plates, and for this purpose he made use of M. Boettger's process.

Very lately the deposition of iron by galvanism has been greatly improved by M. Klein, of St. Petersburg. In 1808 he produced before the Academy of Sciences, of that capital, the results which he had obtained by means of an ammoniacal solution of sulphate of iron, and a Meidniger battery with a piece of iron plate at the positive pole. With these he produced, by precipitation of the iron, not only entire plates of steel from the hardest to the softest, for the reproduction of engraved copper plates, which united the advantages of the softness of the copper for the engravers and the steel-like hardness of the iron for printing from. He also applied the method to the production of various articles in iron. In all cases the iron precipitated by M. Klein is very brittle, and he found that it was combined with hydrogen, and that its specific gravity was not more than 7.675, that is to say, a little more than rolled iron, but the hydrogen was driven off by annealing, which gave the iron the density of 7.811, which is greater than that of hammered iron, and it then became perfectly malleable, eminently flexible and elastic, and capable of being welded; in a word, possessing all the characteristics of excellent hammered iron.

M. Volger exhibited to the Society steel reproductions of engraved plates prepared by M. Klein, a block made up of strips of the deposited iron welded together, forged, filed, and polished, and a shield reproducing perfectly an elaborate *repousse* composition of the "Battle of the Amazons," with a plateau weighing 15 lbs. The most valuable application of electro-iron was pronounced by M. Volger to be in its employment in stereotype works, and especially in the case of printing in colors for the Government bank notes, checks, stamps, etc., as iron is not affected by mercurial pigments which ruin copper, type, and other metals.

CEMENTATION OF IRON.—We find in the *Bulletin de l'Association Scientique de France* a study, by Boussingault, on the cementation of iron for steel. The difference of the material before and after cementation was determined by the most accurate methods with the following result:

	Before Cementation.	After.	Difference.
Weight used	4949.45	4994.20	+44.45
Iron	4905.00	4914.30	— 0.70
Carbon	5.84	49.60	+43.85
Silicon	5.20	5.34	+ 0.14
Sulphur	0.59	0.30	— 0.29
Phosphorus	4.95	6.24	+ 1.29
Manganese	10.99	10.99	none.
Other elements	16.98	17.33	+ 0.35

The most important deduction from the above is the fact that the sulphur is eliminated by fusion to the extent of one-half; a fact probably explaining the better quality of steel made from cemented iron. The loss of iron is probably due to the formation of chloride by reaction on the alkaline chlorides, in the cement powder.

RAILWAY NOTES.

RAILWAY PROJECTS IN THE EAST.—At a recent meeting of the Société de Géographie, a letter was read from M. de Lesseps, stating that his son, M. Victor de Lesseps, and Mr. Stuart, an English engineer, had returned, after ten months' exploration on the frontiers of Afghanistan and among the Himalayas. Their observations and unpublished geographical works placed at their disposal by the Indian Government gave a choice of three routes for railway communication between India and Russian Asia:—1. From Peshawur to Caboul, Balkh, Samarkand, Tashkend, Fort Orsk, and Orenbourg. 2. From Peshawur by the valley of the river Caboul, Chitral, the Pamir table-land, the basin of the Yarkand river, the towns of Yarkand, Kashgar, Kokand, Tashkend, Ekaterinbourg or Orenbourg. 3. From Lahore to the course of the Seloum, the river Nedridge, Shyok, Karakorum, the rivers of Yarkand, Kashgar, the towns of Kokand, Tashkend, valley of the Jaxartes, and Ekaterinbourg or Orenbourg. The first and second of these, though practicable from an engineering point of view, seem excluded on other grounds; fanaticism and civil wars prevailing in the territory to be traversed up to the Russian possessions would even preclude surveys from being made, and both Russia and England would be hostile to any project involving their intervention in the affairs of Afghanistan. As for the third route, which alone seemed feasible to the explorers, the crossing the Himalaya and Cashmere chains would be a serious undertaking; but the explorers found out that by following the valley of the Seloum and ascending to Srinagur, the capital of Cashmere, great heights might be reached by gradual slopes, as was stated before their departure by the late M. Elie de Beaumont, whose statement that the rock to be cut in case of a tunnel between one valley and another would be softer than in European mountains, had also been confirmed. The greater length of the line would be compensated by security to life; for, whereas no traveller could go from Peshawur to Tashkend by Afghanistan without danger, a journey between Lahore and Yarkand offered no serious perils. The explorers met Mr. Russell in the Himalayas with 600 mules laden with English goods, while merchandise from Yarkand is now sold in London. Cashmere, moreover, is under a tributary of the Indian Government. Eastern Turkistan or Kashgar is governed by an intelligent young sovereign, Yakoob Beg, who had just concluded a liberal treaty with England. His capital, Yarkand, with 300,000 inhabitants, would become the junction between the Anglo-Indian and the Central Asian lines, as also the starting point of a direct line to China. When England, added M. Lesseps, sees

Russia extending her railways from Central Asia to Tashkend and the frontiers of Eastern Turkistan, she will not like to remain outside the great commercial traffic which will result from it. She will hasten to promise the survey and construction of a railway facilitating her commercial interests with Central Asia and Western China.

NATIVE RAILWAY ENGINEERS FOR INDIA.—It has long been apparent that if the extension of Indian railways was meant to keep pace with the expressed desires of the Government, the lines must be conducted by native agency with a moderate amount of European supervision. At present few of the natives know much about practical mechanics, and men who have a familiar acquaintance with the branches which are most essential in railway practice are extremely rare. The mere introduction of European skill and appliances in various manufactures and public works, especially railways, which has taken place to a large extent of late years, has indeed produced an unpremeditated education in mechanics among the quick-witted Hindoos; and natives who can manage a steam engine have long been found in the presidency towns. There are a few of them who are even capable of driving a locomotive engine, although many engineers of experience express doubts whether the nerve and readiness of mechanical resource required to make a good driver are likely to be found largely among the natives of India. The local government, which evidently does not share in this opinion, has determined to make a systematic attempt to train native engine drivers and mechanics of all kinds, as well as plate-layers, for the service of the State railways to assist the European agency in this department. If the experiment should prove successful, not only will a considerable saving be effected, but a new field of employment will be opened up for the natives themselves. In regard to plate-laying, it is thought that the object may be obtained by allowing to the inspectors on the various State railways an apprentice fee for every native they instruct and turn out a really qualified foreman plate-layer, capable of superintending the maintenance of twenty to thirty miles of railway. Such men could readily command ten shillings a week, which is excellent local pay; and Lord Northbrook is anxious that the experiment should be tried immediately. As respects the instruction of natives as engine drivers, it is of course essential that a driver should have served in workshops, and be qualified not merely to keep his engine in good going order and drive it, but if anything goes wrong, to find out the source of the mischief and rectify it. Hitherto few natives have passed from the workshops to be employed as drivers; but the Government of India thinks that this state of affairs might be remedied without much difficulty. In the opinion of those who constitute it, with a proper selection of intelligent men, physically fitted for such work, and with careful training, both in and out of the shops, a better result may be looked for, more especially with the lighter engines and slower speed of the metre gauge lines. A great deal will naturally depend on the earnestness and aptitude of the instructors, and especial care must be taken to insure a close control over the men, particularly as regards the proper charge being taken of the engines consigned to their hands. It has also been suggested that an attempt should be made to train some of the native sappers and miners to the duties connected with the construction and maintenance of railways. Suitable occupation could readily be found for them in times of peace, while in war time they would naturally prove very useful. This is a question which remains open for the consideration of the military authorities; but if it should meet with their approval, it would be easy to arrange on the State railways for the training of a company, or a selected portion of each company, on all the special details of railway construction, etc.; and it is probable that from among such a number of men individuals would be found willing to go through a course of training in workshops, and to perform the duties of engine drivers efficiently when the educational period ended.—*The Engineer.*

ENGINEERING STRUCTURES.

PORT SAID.—The Suez Canal Company is lengthening the western mole of Port Said, and clearing away the deposit which on that side of the entrance was fast encroaching upon the already somewhat narrow channel leading into the port. It is intended to carry the breakwater on that side out into six fathoms of water, when its total length will be about 10,340 feet. Some 200 feet were completed last year, but the whole will not be finished for another three years at least. The company has taken over the concrete manufacturing establishment of Messrs. Dussand, and it is now making concrete on its own account. Hydraulic lime, sea sand, and water were formerly used, but small stones obtained from the Greek Islands have now been found to answer the purpose better than sea sand. The breakwaters as barriers to the sea are everything which could be desired, but below water there are numerous open spaces through which sand brought down by the Nile current finds its way.

NEW HARBOR AT DOVER.—Her Majesty's government will, it is authoritatively stated, early in the next season of Parliament, introduce a bill for the speedy execution of a plan which has been recently agreed upon between the various public departments for the construction of a large military and general harbor at Dover. The harbor which the government have resolved to construct will cover an area of about four hundred acres, with a depth varying at low water of spring tides from one to six fathoms. It will serve at once as a packet harbor, a coaling-station for men-of-war of all sizes, a commercial harbor to be used subject to the payment of tolls, a depot for munitions of war, and a harbor of refuge on a small scale. Such a harbor, protected by the batteries near the castle and on the western heights, and by a large fort now in course of construction on the Admiralty Pier, would be of great advantage to England in case of a European war. The whole coast of France from the mouth of the Seine, and the whole coasts of Belgium and Holland, would be commanded by a small fleet which should make Dover the basis of its operations, and, indeed, almost any North Sea fleet would naturally send its vessels to coal at Dover, if accommodations for the purpose were once provided within so short a distance of London, and opposite the new harbor which has just been undertaken by the French government.

between Calais and Boulogne. It is expected that the bill will pass without opposition by the end of March, and that the works will be actually commenced by June next at the furthest. These works will cost, as near as possible, a million pounds sterling. This money it is proposed to obtain from the Public Works Loan Commissioners, at a rate of 3½ per cent., in such sums as may be from time to time required, so that Parliament, having once passed the bill that is now being prepared, will not be called on to provide any more funds. The cost of the works will be refunded by a toll of 1 shilling per head on passengers landing or embarking, by an annual rental from the South-Eastern and the Chatham and Dover Railway Companies, and by the usual harbor dues, ground rents, receipts for wharfage, and the like, the total annual revenue being calculated at something between £35,000 and £40,000. This will pay the interest and provide a sinking-fund, by means of which the cost of the works will be repaid in something like, it is believed, twenty-five or thirty years, or, if the traffic continues to increase in anything like its present ratio, in a much shorter period. The works will be carried out under the direction of Mr. Edward Druce, C. E., who has been for twenty years resident engineer at the Admiralty Pier. The materials will be almost exclusively the concrete blocks which have been so largely used below water in the existing works, and some of which that have been immersed for fifteen years, and have recently been recovered, show no signs of deterioration, and are, indeed, additionally bound together by growths of mollusca. When the new harbor is completed—even when the new packet pier is finished—and when the French government has got the new port at Audrecelles, that has just been sanctioned, ready for use, there will be no longer any excuse, whether the *Castalia* and *Bessemer* succeed or fail, for the inferiority of the steamers on the Straits of Dover to those beautiful boats which have now been running most successfully and remuneratively for over ten years between Dublin and Holyhead; indeed, there will be no reason why the passage from Dover to the new port under Cape Grisnez should exceed an hour, or seventy minutes at the most, in ordinary weather, while the mails and passengers will be able to cross, no matter how bad the weather might be, which is not always the case at present.—*Iron.*

BOOK NOTICES.

THE BLOWPIPE; A GUIDE TO ITS USE IN THE DETERMINATION OF SALTS AND MINERALS.—Compiled from various sources by GEORGE W. PLYMPTON, C.E., M.A. New York: Van Nostrand, Murray and Warren Streets. London: Trübner & Co., Ludgate Hill. Price $1.50.

For the rapid determination of the approximate composition of minerals the blowpipe is, when ordinary care is used, thoroughly reliable, and at the same time most convenient for the practical man, owing to the extreme portability and compactness of the whole apparatus required for making the tests; and to facilitate the acquisition of the knowledge necessary for its successful use, Prof. Plympton, of the Polytechnic Institute, of Brooklyn, N. Y., has compiled this very useful little volume, designed especially for the learned. In the first and second parts, which treat of the apparatus and reagents, and of the general examination, Sheerer and Blanford have been chiefly followed, while in the third part, in which the various methods for the determination of minerals, by the aid of the blowpipe, are explained, Guerout's Guide Practique, translated from the manual of Dr. Fuchs, of Heidelberg, has been taken as the basis, but throughout the volume Prof. Plympton has introduced emendations and improvements of considerable importance, and which adapt the book to the requirements of English and American readers. It is remarked, that, perhaps, during the last fifty years no department of chemistry has been so enriched as that relating to analysis by means of the blowpipe. Through the unwearied exertions of men of science the use of this instrument has arrived at such a degree of perfection that we have a right to term its use analysis "in the dry way," in contradiction to the analysis "in the wet way." The manipulations are so simple and expeditious, and the results so clear and characteristic, that the blowpipe analysis not only verifies and completes the results of analysis in the wet way, but it gives in many cases direct evidence of the presence or absence of many substances which would not be otherwise detected without a troublesome and tedious process, involving both prolixity and time; for instance, the detection of manganese in minerals.

It being essential to the blowpipist that he should be not only well acquainted with the nature and use of the various pieces of apparatus, but that he should know which form is the most convenient and of greatest general utility, Prof. Plympton devotes a couple of dozen pages to the consideration of the utensils—the blowpipe, the lamp, the charcoal, and platinum supports, iron spoons, glass tubes, and other apparatus necessary; and then describes the reagents, and explains the method of testing their purity. It is gratifying to find that the author has not only adopted the modern chemical notation, but that he has also, in one or two cases, used the metric measures. It is a most remarkable circumstance that the Americans, usually so quick to recognize improvements, and so clever in making them themselves, should in the two important points of chemical notation, and the adoption of the metric system of weight and measures, have suffered themselves to be left so far behind by less progressive European nations. Even in England, the very hot-bed of prejudice, the metric system, from its unquestionable superiority, has long since been adopted by the leading scientific and especially chemical writers, although the stupidity of the general public has not yet been overcome, and in Germany, where the relations with France have rendered anything of French origin particularly unpopular, the undoubted advantages of the metric system have led to the adoption of the exact half kilogramme as the Zollpfund, or unit of weight, the Zollcentner being 50 kilogrammes, and the Ton 1,000 kilogrammes. Yet in America, where the existence of a decimal coinage renders the adoption of a corresponding system—the metric system—specially desirable, there is as much opposition as if the nation were antiquated and effete. Let us hope the time is not far distant when the metric system will become universal. Having been taught the use of the apparatus and reagent to be employed, the student is next introduced to the initiatory analysis—the examinations with the glass tube, open tube, and

charcoal in the platinum forceps, borax bead, microcosmic salt, and carbonate of soda; and the confirmatory examinations, ample tables being provided to facilitate his researches. In the third part, treating of the determination of minerals by the aid of the blowpipe, the various minerals are classed according to its behavior on charcoal, whether it volatilizes or burns, emits a given odor, gives off fumes of antimony, coats the charcoal, or leaves a characteristic residue; to its behavior with carbonate of soda, in the borax lead, or with cobalt solution; according to the effect produced upon it by hydrochloric acid, and so on, so that the group to which a mineral under examination belongs is readily ascertained, and there will be scarcely more difficulty in deciding which particular member of the group it is.

For the practical man requiring a comprehensive and portable volume few better than Prof. Plympton's could be recommended. The general character of Scherer and Blanford's is too well known and appreciated by professors and students to render any special commendation of the first and second parts necessary; while with regard to the third part, the arrangement is at once simple and excellent, it is concise, yet gives all the necessary information, leaving really nothing to be desired by those who take the book for their guide.
—*London Mining Journal.*

A Handbook of Applied Mechanics. By Henry Evers, LL.D. London and Glasgow: W. Collins, Sons & Co., 1874. Price 75c.

This is one of Collins's Elementary Science Series, and is quite equal in merit to the other members of perhaps the most valuable of all the cheap collections of scientific manuals which recent events have educed in such overwhelming numbers. After a general introduction, in which the elements of applied mechanics are recapitulated, the author treats in succession of the properties of the chief woods used by machinists, and then passes to the metals, explaining the modes by which they are procured and their various properties. Water as applied for mechanical purposes is next treated of, and then follows a practical dissertation on the strength of materials, and a description of the tools and machines employed in the mechanical arts. Well-executed illustrations are freely supplied, with a useful and sufficiently copius index, a prime requirement in a book of this, or indeed any kind.—*Iron.*

Hints to Young Engineers. By J. W. Wilson, C. E. London. For sale by D. Van Nostrand.

A useful *brochure* by Mr. J. W. Wilson, C. E., Principal of the Crystal Palace School of Practical Engineering, has been published by Messrs Spon, of Charing Cross. The value of the practical advice, of which the little work contains much, is not impaired by the pleasant vein of dry humor that crops up at intervals. It is very readable, and thoroughly practical, such, in a word, as few readers, professional or other, can fail to enjoy and profit by.

Mineralogy. By F. Rutley, F. G. S. London: Thomas Murby, 1874.

Into this little manual, which is one of Murby's Science and Art Department Series, the author has compressed a large amount of instructive matter, very lucidly arranged, and selected with judgment, so as to suit the requirements of beginners, the minerals being grouped according to their most prominent basic constituents, and each group being prefaced by a sufficient description of its leading characters, chemical and physical. The introductory definitions and general descriptions will be found very useful, as will also the instructions in the use of the blow-pipe; and the diagrams in the crystallo-graphic portion are drawn on a novel plan, and are better calculated to give exact ideas of the form and relation of the planes of the crystals than that on which they are generally represented. The subject of polarization is treated with unusual clearness.—*Iron.*

Color. By A. H. Church, M. A. London: Cassell, Petter & Galpin. Price $1.00.

This is a new edition to Cassell's Technical Manuals. It is abundantly and beautifully illustrated, and will be read with interest by the general reader, but it is furthermore so complete in its array of facts as to be of valuable service to the student and lecturer.

Manual of Toxicology. By John J. Reese, M.D. Phila. J. B. Lippincott & Co. $5.00.

Although this field of scientific labor has been ably worked already, and the results abundantly recorded, yet we trust the present treatise will be well received.

The reputation of the author will secure earnest attention to his writings. Much is written that has been presented before, but in a familiar, easy reading style that is the author's own. More than the usual space is devoted to the medico-legal part of the subject; and two subjects—"Post-Mortem Imbibition of Poisons," and "Duties and Privileges of Medical Experts" are treated for the first time at considerable length.

Manual of Determinative Mineralogy, with an Introduction to Blow-Pipe Analysis. By Prof. George J. Brush. New York: John Wiley & Son. For sale by D. Van Nostrand. $3.00.

This excellent supplement to the "Descriptive Mineralogy" of Dana has been long expected, and will prove very acceptable to students.

The first portion of the work is devoted to a "Systematic Course of Qualitative Blow-Pipe Analysis," mostly arranged from Berzelius and Plattner, and is quite complete enough as a preparation for the remaining portion of the work—Determinative Mineralogy. This portion consists entirely of tabular classifications of minerals, based upon the reactions afforded by "simple chemical experiments in the wet and dry way."

It is an indispensable aid to the student of mineralogy.

Outlines of Proximate Organic Analysis, for the Identification, Separation, and Quantitative Determination of the More Commonly Occurring Organic Compounds. By Albert B. Prescott, Professor of Organic and Applied Chemistry in the University of Michigan. New York: D. Van Nostrand, 1875. 12mo, pp. 192. $1.75.

This is the first and only book published in the English language which attempts to give, in concise form, the reactions of organic substances. Proximate organic analysis has not yet been re-

duced, like mineral analysis, to one complete system. For many organic substances there are no distinct tests, and no means have been discovered for separating them from other bodies with which they are combined. There are, however, certain classes of bodies which permit of isolation by fractional distillation, by solution, or by precipitation, and some of these, like the alkaloids, give characteristic colors with certain oxidizing agents. Many other well-known organic principles give characteristic reactions when by themselves. Some of these are carefully given in works on toxicology, or in the pharmacopœias, while others are scattered far and wide through chemical dictionaries, and in the proceedings of chemical societies, and in the pages of chemical journals. Professor Prescott has done a great service to the analyst in collecting together so many of these reactions, embracing the tests for more than 200 organic principles, and publishing them in a neat little volume at a price within the reach of all.

The author arranges the organic bodies of which he speaks under the following general heads:—Solid Acids, volatile and non-volatile; Liquid Acids, volatile and non-volatile; Fatty Acids; Neutral Substances, liquid or fusible; Bases, liquid and solid; Glucosides and other solid neutral substances; Nitrogenous Neutral Bodies; Carbohydrates; Alcohols and their products. The new notation is used throughout, and the work is evidently up with the times. A book so long needed cannot fail to meet with the reception it deserves.

—*Journal of Applied Chemistry.*

MISCELLANEOUS.

THE COLORATION OF METALS.—It is possible to color metals rapidly and at very little expense by means of covering their surface with a film of a sulphurous solution. In some minutes, by means of this composition, any objects in brass or gun-metal can be given a tint of gold, of copper, of carmine, of maroon, of bright analine blue, a paler blue, and finally a pinky white, according to the thickness of the film, which again depends upon the time during which the metal is plunged into solution. The colors thus obtained have a beautiful lustre, and if the objects have first been subjected to the action of acids or of alkalies, the colors adhere so intimately to the surface of the articles that they will resist the action of the tools used to polish them. To prepare the solution, 42.5 grammes of hyposulphite of soda is mixed with 450 grammes of water; to this must be added 45.5 grammes of acetate of lead, dissolved in 225 grammes of water. In raising this solution to a temperature of 190 deg. to 200 deg. Fahr., it is decomposed, and the sulphide of lead is precipitated in the form of black flakes. If the metal is present, a portion of the sulphide of lead is deposited on it, and the colors, as we have before described, are produced according to the thickness of the deposit. In order that they should be uniform it is necessary to heat the objects equally throughout. Iron thus treated takes a steel blue; zinc takes a brown color. If in the place of acetate of lead an equal quantity of sulphuric acid is added to the hyposulphite of soda, and the operation is carried on in the same manner, but at a slightly higher temperature, gun-metal or bronze becomes a beautiful red, then green, and finally an irradiated tint of green and red most striking and beautiful. This last color deserves remark from the fact that it is durable, which is not the case with all the other colors. It is possible to obtain most beautiful imitations of marble by means of a plumbic solution thickened by adragant (tragacanth) gum applied to bronze previously heated to 210 Fahr. It is treated finally with the ordinary solution of sulphide of lead. This solution will serve for many operations.—*Iron.*

ROUND THE WORLD.—An English paper says: The following comparative statement of distances, time, and fares applies to existing conditions of first-class passengers from Liverpool by the American route, and from Southampton by the Suez route.

DISTANCE, TIME, AND FARES.

Via Suez Route.				Via American Route.		
Miles.	Days.	£.	To	Miles.	Days.	£.
11,268	56	103	Yokohama	11,382	34	72
10,518	53	103	Shanghai	13,032	42	82
9,648	48	93	Hong Kong	13,002	40	82
13,259	62	102	Auckland	12,290	44	82
11,999	57	88	Sydney	13,220	47	82
11,439	56	88	Melbourne	13,780	48	82

The best statement of the aggregate fares, time, and distances that we have seen is as follows:

THE MODERN ROUTE AROUND THE WORLD.

	Miles.	*Days.*	*Hrs.*
London to Liverpool	200	—	5
Liverpool to New York [Mail Steamer]	3,000	10	—
New York to Chicago [Railway]	890	1	5
Chicago to Omaha [Railway]	490	1	—
Omaha to San Francisco [By Union and Central Pacific Railways]	1,914	4	6
San Francisco to Yokohoma	4,764	19	—
Yokohma to Shanghai [Steamer]	1,200	4	—
Shanghai to Hong Kong [Steamer]	870	4	—
Hong Kong to Calcutta [steamer, via Galle]	3,500	22	—
Calcutta to Bombay [Railway]	1,400	2	—
Bombay to Suez [Steamer]	3,600	14	—
Suez to Alexandria [Railway]	225	—	12
Alexandria to Brindisi or Venice [str.]	850	3	—
Brindisi or Venice to London [Railway]	1,200	3	—
	24,103	88	4

Fare for the above route.....£195

Under these conditions, it is not an over-sanguine belief that the current of travel is turning more decidedly toward the American route.

ASSOCIATION OF FOREMEN MECHANICS.—This peculiar weakness of our practical foremen may seem a small matter to so gravely discuss, but we hold that we have in a great measure to thank this foible, or "rule of thumb," for our present superiority over many French manufacturers, and our considerable inferiority to America in the marketable production of novelties. In the case of French engineers especially, they are so fond of designing and working theoretically that the natural instinct of the eye is allowed no play, and they frequently find themselves on the wrong side for strength. Whereas, in our own workshops, we believe that the eye has often saved our reputation at the expense of imperfect theory. On the other hand, in the case of America, they are entirely without traditional precedents, and thus, when a certain object has to be obtained, the American sets to work, perfectly untrammelled in his ideas, to effect his purpose in the readiest manner. This

gives a certain peculiarity and eccentricity to his designs for the commonest articles, which would strike an English eye at once, and perhaps are not to be imitated with advantage; but at the same time we see the most surprising and revolutionizing novelties, designed, manufactured, and in large demand, before we in Britain would have decided that the arrangement was practical. However, our foremen will no doubt learn wisdom, and the knowledge that "novelty" does not always mean "impracticability" by the continued success of so many transatlantic novelties, and the above Association is just the sort of place in which to do so. We wish it every success and increase; and if this should meet the eye of any enterprising unattached foreman, he cannot do better than attach himself at once to the Association; and we hope that he and all his fellow foremen will take the hint that prejudice and dogmatism are generally the mark of an *ignorant*, and not essentially of a *practical* man.—*Iron.*

CHINAMEN PROTESTING AGAINST THE INTRODUCTION OF RAILWAYS INTO THE CELESTIAL EMPIRE.—Two very curious articles have been published by a Shanghai native newspaper, the *Hwei-Pao*, protesting against the construction of railways in the Chinese empire. The *Hwei-Pao* is of opinion that the existence of railways in Europe is too recent to admit of a judgment being formed as to their practical utility, and, moreover, that there is not sufficient business in China to render them profitable. The Chinese journal goes on to say that "tea and silk are the principal objects of commerce, and these have hitherto been forwarded to the treaty ports by river steamboats. A substitution of railways for steamboats would not effect any saving in point of time, and could not, therefore, even from the point of view taken by the foreigners themselves, be of any service to China. Admitting that a little time was gained, the Chinese would not be benefited, for the goods would not be exported more rapidly. Thus the railways would only lead to an accumulation in the ports of vast quantities of goods, which, as they could not be shipped off all at once, would fall considerably in price." The *Hwei-Pao* also says: "The accidents on the railway lines are very numerous, caused by collisions, by the engines or tenders taking fire, by the trains running off the lines, or by the bridges giving way and the trains being precipitated into the rivers below. In other cases the carriages are injured by the great speed at which they are hurried along, and the accidents are so numerous that it is often impossible to ascertain the exact number of dead and wounded. All the foreign journals are full of details concerning these accidents. But, admitting that most of these casualties are preventable, and that the trains follow their regular course, they travel quicker than the thoroughbred horse, and the people walking on the lines would have no time to get out of their way. From this cause alone the number of fatal accidents would be enormous. In all countries where railways exist they are considered a very dangerous mode of locomotion, and beyond those who have very urgent business to transact, no one thinks of using them." This latter statement cannot as yet be accepted in its entirety; but unfortunately, we have every reason to know that, so far as England is concerned, travelling by railway is "a very dangerous mode of locomotion."

—*Railway News.*

CARBONIC ACID GAS AS A MOTIVE POWER.—Our readers are well aware that from time to time various substitutes for steam as the motive agent of engines, more or less similar to those which are in ordinary use, have been proposed. It cannot be said that as yet any have been attended with that practical success which was to be desired. This is, however, no reason why further efforts should not meet with a more favorable result, and we have had laid before us, certain proposals which appear of a very valuable character; though of course in this, as in other matters, experience will have to decide the problem.

Carbonic acid gas naturally suggests itself as a likely subject for experiment. It may be reduced into a liquid state by the compression of its own molecules under a pressure of some 33 atmospheres, and the merest tyro will at once see what an immense reservoir of force carbonic acid gas so treated must be. Dr. D. W. Gwynne, noting this, has for some time been engaged in devising means for utilizing this property of CO_2; and has arranged a complete system for its production and application, the plans for which were forwarded by him to the Earl of Caithness some six months since.

Dr. Gwynne generates his CO_2 by the treatment of some substance containing it in combination by an acid. Limestone, chalk, the carbonates of the alkalis, etc., would yield an inexhaustible supply, and the acid might either be sulphuric or hydrochloric. Where economy of space is a consideration a bicarbonate of an alkali could be employed. But under ordinary conditions chalk or limestone would answer every purpose. The chalk, or whatever else was employed, would be acted upon by the acid in a closed receptacle or generator, a general idea of which would be supplied by one of the cylinders used in the manufacture of ærated waters. The generator would be fitted with a gauge, and suitable means for attaching it to a receiver. A double cock or collar would serve to cut off the connection with the receiver, and the gauge would show the pressure. The receiver represents precisely the steam-chest of an ordinary steam-engine, and as such an engine may, and often does, have several boilers, so to each receiver may be attached any number of generators required, determined by the needed amount of power. From the character of the fittings one or more generators may be removed or replaced without interfering with the tension of the gas in the receiver. Under the receiver Dr. Gwynne places a small furnace; and as the tensive power of the gas is greatly increased by the addition of heat—1.480 volume for each degree—the value of this arrangement will be seen.

By Dr. Gwynne's process it is easy to obtain gas which would exercise a power of 30 atmospheres without liquefaction. Such a pressure, however, would, in his view, never be required, and any graduated pressure from 1 up to 30 could readily be obtained by due regulation of the apparatus and materials. As the deadly nature of the gas (which causes closure of the glottis or attempted inhalation) requires a provision for its neutralization in its escape from the engine, Dr. Gwynne has met this by passing the escape pipe into a tank of lime-water.

Such in brief is an outline of a plan which well deserves attention. Sooner or later some substitute for steam must be found, and he is a public benefactor who labors to that end.

—*Mining Journal.*

A_1

B_1

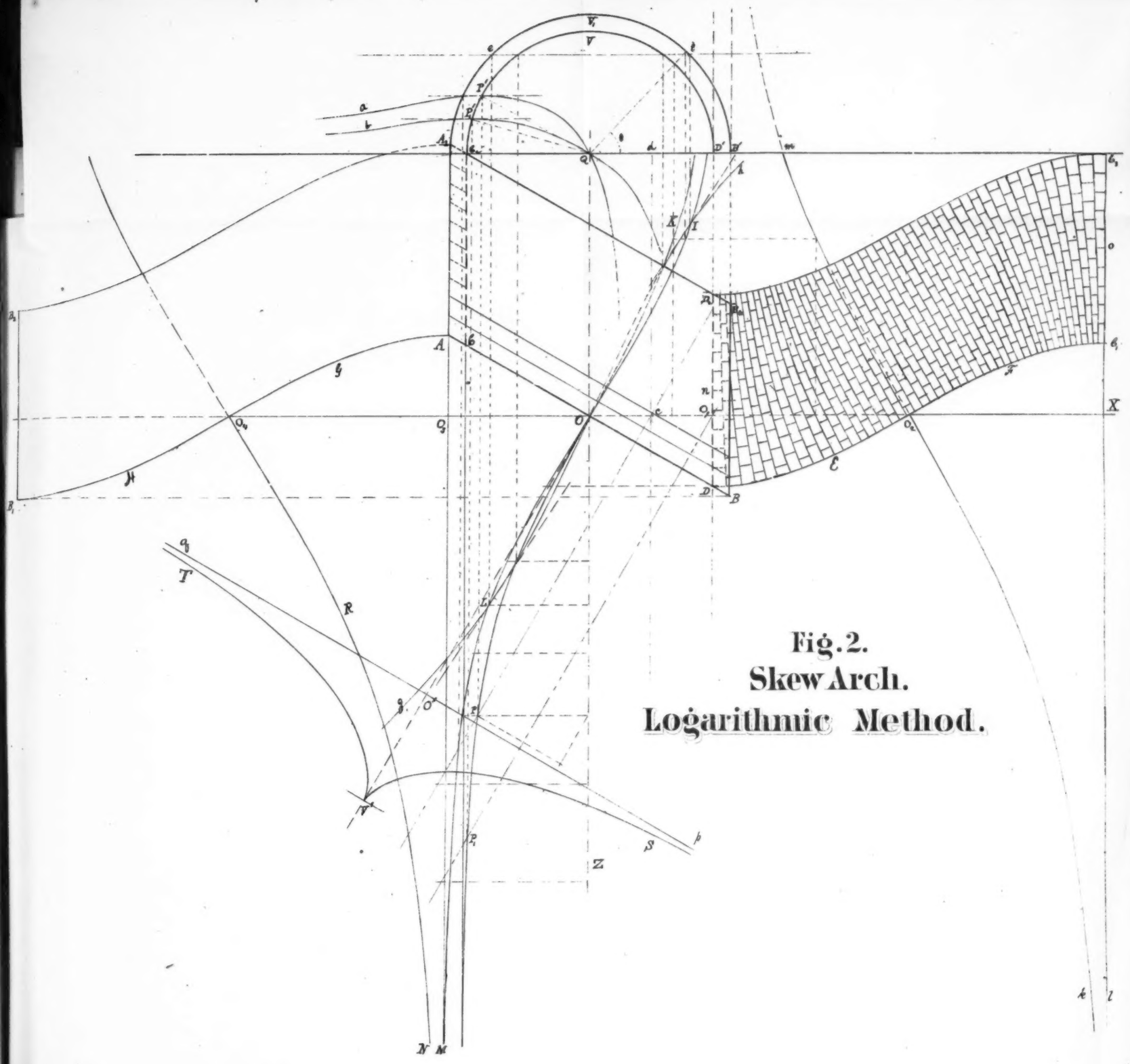


Fig. 2.
Skew Arch.
Logarithmic Method.

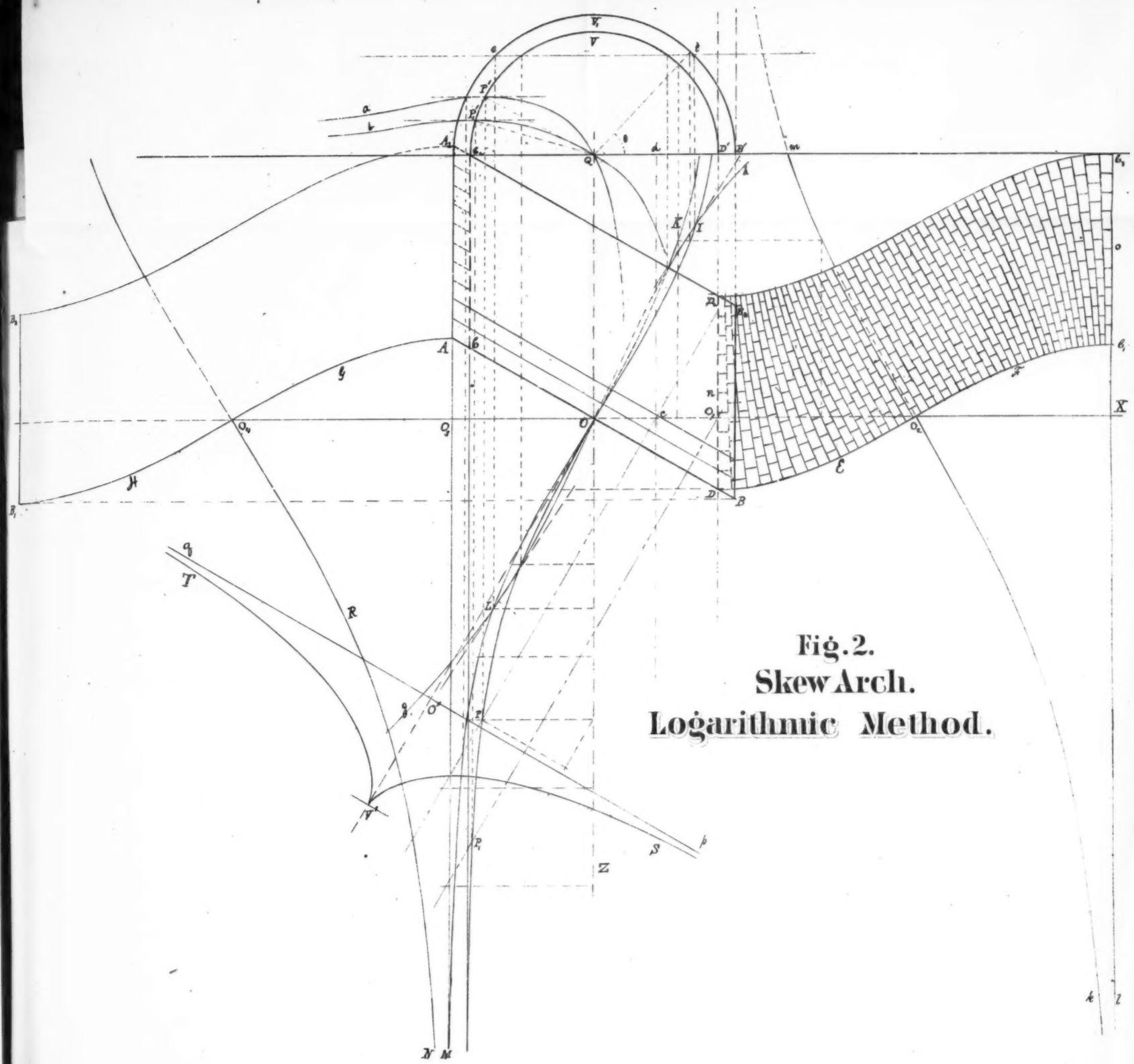


Fig. 2.
Skew Arch.
Logarithmic Method.